NSRP-0050

SHIP PRODUCIBILITY PROGRAM
TASK S-1
PROPULSION PLANT STANDARDS
FEASIBILITY STUDY

JUNE 1975

PREPARED FOR: BATH IRON WORKS CORPORATION BATH, MAINE

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1.0 INTRODUCTION

1.1 BACKGROUND. This report summarizes the results of an evaluation of application of standards to marine propulsion power plants. This study supplements a major effort by M. Rosenblatt and Son, Inc., on the same subject. These studies were in support of the Ship Producibility Program sponsored by the Maritime Administration (MarAd).

"1.2 OBJECTIVE. The objective of this study was to determine potential cost savings by standardization of main propulsion components for a particular single ship design.

1.3 WORK STATEMENT. (MEMO OF UNDERSTANDING). Ingalls Shipbuilding's (ISD) efforts followed the six specific tasks of the Work Statement documented in Appendix A.

1.4 SCOPE OF EFFORT. Ingalls Shipbuilding's technical effort, based upon the Memo of Understanding consisted of six basic items:

a. Definition and layout of four propulsion plants for a 150,000 deadweight ton (dwt) tanker including steam, medium speed diesel, heavy duty gas turbine and aircraft derivative gas turbine plants.

b. Definition of three levels of standards applied to the components of the four propulsion plants listed above:

(1) A full description of the components of each plant in a data package unique to each vendor's component

(2) An interface and performance specification applicable for all components of a given size range

(3) A standard procurement specification.

c. Estimation of the cost differential to Ingalls Shipbuilding by the application of the three levels of standards described above to the propulsion plant to the 150,000 dwt tanker. This economic analysis includes the effect on engineering man-hours, production man-hours, and procurement related costs.

d. Contact 6 to 8 key propulsion component suppliers to solicit information on:

(1) The merits of the types of proposed standards

(2) The acceptability of the proposed types of standards

(3) Approximate costs of developing the data type of standard.

e. Review and comment on Rosenblatt's standards selections and definitions of propulsion standards prepared as a part of their Bath Iron Works (BIW) study.

f. Prepare a report covering the results of the five tasks itemized in efforts (a) through (e).

The effort in each instance was confined to a 150,000 dwt tanker" with four types of propulsion units as mentioned previously and each propulsion unit was in the vicinity of 26,000 SHP.This

limited application will indicate cost differentials for each type of propulsion unit when compared to the various methods of contemplated standardization. Other classes of vessels can then be analyzed by extrapolation.

2.0 DESCRIPTION OF STANDARDS

2.1 The levels of standards were defined by ISD as follows:

I. The baseline was defined as present method of design, procurement, and installation of the various components. Each procurement requisition is prepared independently and the design is developed upon receipt of vendors' plans.

II. Standard procurement specifications for each component of each propulsion system are prepared in a manner to properly describe acceptable material from various vendors. Necessary restrictions are imposed to assure suitability. However, proprietar restrictions pertaining to specific vendors are prohibited.

III. The various equipment manufacturers prepare a standard data package for each component which includes design data, physical performance, contractual and installation information This document is prepared in a standard format suitable for filing and ready use.

IV. The components of each of the four types of propulsion plants are identical in performance, mounting and interface with connecting services. Manufacturers of the major components are required to modify their equipment by redesign and/or extension to comply with the above requirements. Plans and specifications are prepared for immediate issue.

These standards definition differed slightly from the levels and types of standards defined in the Rosenblatt study. The matrix below clarifies the difference.

ITEM	ISD	ROSENBLATT
BASELINE (CURRENT PRACTICE)	I	I.
PROCUREMENT SPECIFICATION STANDARD (ONLY)	II	
DATA STANDARD (WITHOUT PROCUREMENT INFORMATION)		II
COMPLETE DATA PACKAGE OR PROCUREMENT STANDARD	III	III
HARDWARE STANDARD	IV	IV

3.0 STUDY APPROACH

3.1 DEFINITION OF STUDY TASKS. M. Rosenblatt and Son, Inc., conducted an extensive study on the shipbuilding activity anticipated in the next decade. This forecast was organized by ship type, size, propulsion method, shaft horsepower and time period. From this, they were able to determine the quantity of ships to be constructed in the United States. Further analysis indicated the most desired cargo capacity and shaft horsepower. Based upon current popularity among the operators, steam was selected by M. Rosenblatt for detailed study.

M. Rosenblatt contacted various vendors and one shipyard to determine the acceptance of the standards approach. The findings were presented at a council-meeting.

This presentation indicated the necessity to conduct an in-depth study. Ingalls Shipbuilding agreed to pursue this type of study for a particular ship type and, in agreement with Bath Iron Works; Inc., included various methods of propulsion. Ingalls felt that diesel and lightweight (aircraft derivative), and heavy duty gas turbines were gaining in popularity and-would become major contenders during the next decade. Equal effort was expended on each type. Ingalls study was to complement that of Rosenblatt on steam plants.

3.2 STUDY PLAN. The overall approach to the study effort is best described by a flow diagram (see figure 1).

3.3 PRELIMINARY EFFORT. To properly analyze the anticipated cost of procurement and installation, it became necessary to prepare machinery descriptions for the power plants. (see Appendix B). This appendix includes a description and tabulation of the components of each of the four types of propulsion machinery. Machinery arrangements were prepared to determine the feasibility of installation and establish the power plant designs. These drawings are included in Appendix B. Each type of power plant is depicted as an unmanned installation and is shown in enough detail to assure conformance with the physical limitations of the allotted area. The design effort led to the scoping of the engineering effort described in paragraph 4.2.

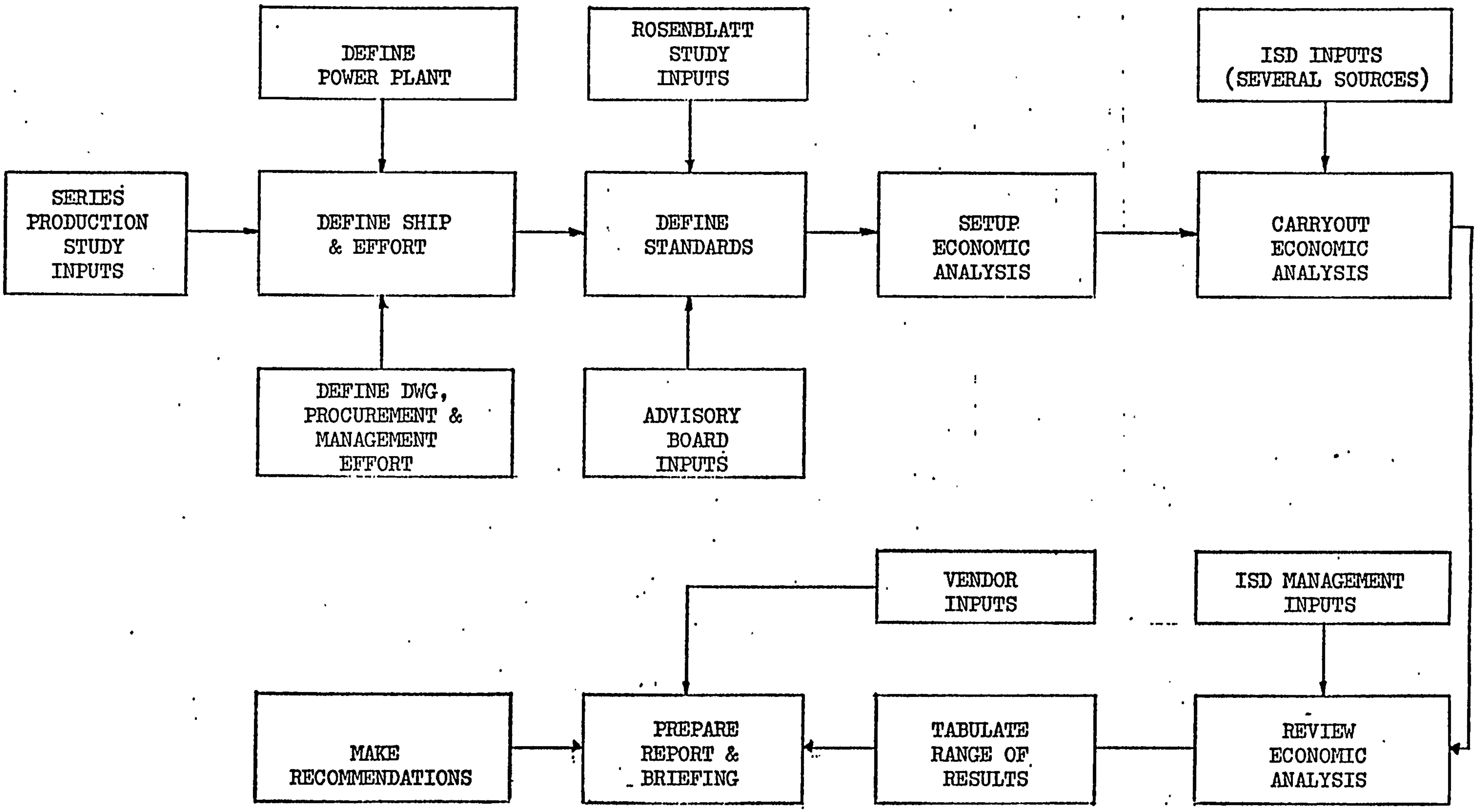


FIGURE 1. STUDY EFFORT APPROACH PLAN.

3•4 COST ANALYSIS . Basic cost analysis forms, Appendix C, were prepared to reflect all known procedures related to the selection, purchase and installation of the various propulsion equipment. These were distributed to senior management personnel for independent inputs for cost comparisons. Three experienced employees, with different backgrounds, developed the data and independently completed the forms. A correlation meeting was held and each participant expounded upon his input. Some adjustments were made based on this review by ISD management. Results from the three independent studies were tabulated anc the percent of contemplated savings for each approach and type of propulsion was determined.

The greatest difference of opinion in the estimated savings was found in the time saving component. This occurs due to the conventional versus the automated approach. Consideration was given to both construction methods. Although dollarwise there is a noticeable spread, all three studies indicate significant potential savings.

The following assumptions and ground rules were established and utilized during the development of the economic analysis:

- Cost analysis would include shipyard (ISD) costs only.
- No costs of implementing standards are included.
- Total procurement, manufacturing and engineering costs would be included.
- All costs would be estimates based on ISD experience.

- o Costs of schedule advantage would be based on yard savings in ship tie up costs - no profit potential of early delivery is included.
- o Profit, G and A and fee would be included, so price changes to owner would be reflected in final dollars.
- o Savings would be presented in changes in total yard effort.
- o Savings would be represented for **a single** ship procurement.

4.0 STUDY RESULTS

4.1 DESCRIPTION OF PLANTS. A preliminary analysis was conducted to determine which power plants were suitable for the 150,000 dwt tanker. These studies indicated that lightweight gas turbines, heavy duty gas turbines, medium speed diesels and steam were suited to the application. The diesel plant application was complicated because three’ engines are needed to meet the horsepower level.

Characteristic	Parameter
Cargo Capacity	150,000 DWT
Range	12,000 Nautical Miles
Speed	16 Knots
Horsepower	25,000 SHP
Fuel	Variable
Propeller	32' Diameter 4 Blades
Shafting	Tailshaft 29.333 in. dia. Lineshaft 23.732 in. dia.

The basic philosophy used in, each of these designs was:

a. Unmanned Machinery Space - The propulsion plants are to be fully automated, with bridge control, to facilitate a complete unattended engine room.

b. Simplicity of Installation - The propulsion plants, turbines and gear, and diesel and gear are to be hardmounted on a common bedplate and then hardmounted on the ship. Packaging of service components into modules will be utilized as much as possible. An example of the use of this type of installation may be in the packaging of the fuel oil service system into a module. The components of the module would be the fuel oil transfer pumps,. fuel oil filters and the fuel oil strainers.

c. Maximum Utilization of Space - The engine room space is to be of minimum volume to provide as much extra cargo space as possible. Bulkhead locations are to remain in the same position, if possible, for the different power plants so that the same basic ship arrangements can be used despite the particular plant. To reduce fabrication costs, fuel storage will be done in double bottom tanks and in full breadth tanks located within the engine room, just aft of the forward engine room bulkhead. No wing tanks are to be used.

Four viable, compact, efficient power plants for a 150,000 dwt tanker are described in Appendix B. Since only the description of the power plants was required for the standardization feasibility study, no effort was made to evaluate the merits of the different plants. Preliminary economic comparisons were made in Appendix D.

4.2 DESIGN EFFORT SUMMARY . To guide the economic evaluation of standards, the number of specifications, diagrams and detail plans were determined for each plant with the results shown in the following tabulation:

Plant Description	No. Specifications	No. Diagrams	No. Detail Dwgs
Steam	44	16	.24
Medium Speed Diesel	2 7	7	1 4
Lightweight Gas Turbine	26	9	15
Heavy Duty as Turbine	3 1	9	75

The titles of each of these documents are included as backup information in Appendix E.

4.3 ECONOMIC ANALYSIS. Various rules and factors were considered to determine the cost of the four types of plants installed using the described approaches. These rules are listed below:

0 Based on engineering estimates by senior management (3 individuals).

0 Anahysis includes propulsion plant only.

0 Three analyses by three independent parties - all three preser

0 Format of detailed estimate is shown in Appendix C.

0 Estimates reviewed by ISD management.

- Effort estimated includes proposal preparation, contract detail design, revisions, yard support, procurement, installation, and trials.
- Hours split into manufacturing, engineering, program management and procurement.
- Fee

  Overhead

  G&A

  Hourly Rates

  Assumed - Only representative values
- Detailed results tabulated in Appendix C for both estimates.

The economic factors used in the analysis were:

Fee	15%
G&A	6%

Hourly Rates - Including Overhead

Engineering	$13.00/HR.
Program Management	10.00/HR.
Procurement	10.00/HR.
Manufacturing	8.00/HR.

Tie Up Cost 1,500/Day

These are typical, not actual ISD numbers.

The results of the ISD economic analysis are listed on Tables I, II, III and IV. The estimate of the number of schedule days saved are shown in Table V. These tables identify a total ISD dollars saved including time saved at the rate of $1,500/day. Note the percentage savings for each of the levels of standards. Tables VI, VII, VIII and IX identify the manpower areas where the savings are the most significant. These are the total engineering manhours required in the areas of contract design, procurement, and detail design.

STEAM

STANDARD TYPE	1	2	3	4
ISD MANPOWER COST	2,947,985 2,953,420 3,085,260	2,930,925 2,869,330 3,025,155	2,716,533 2,428,815 2,611,335	2,714,949 2,379,220 2,543,760
RATIO TO NO. 1 STANDARD BASELINE	0 0 0	0.58% 2.80 1.95	7.85% 17.7 15.36	7.90% 19.4 17.55
TOTAL ISD DOLLARS	3,158,485 3,178,420 3,448,260	3,093,425 3,049,330 3,362,580	2,716,533 2,473,815 2,986,335	2,714,949 2,379,220 2,543,760
RATIO TO NO. 1 STANDARD BASE	0 0 0	2.06% 4.0 2.48	13.99% 22.21 13.40	14.04% 25.51 26.23

DETAILS OF ANALYSIS - SEE APPENDIX IV

TABLE I

DIESEL

STANDARD TYPE	1	2	3	4
ISD MANPOWER COST	2,104,078 2,003,680 2,758,735	2,082,580 1,941,780 2,723,905	1,947,063 1,725,985 2,377,470	1,943,893 1,628,840 2,338,135
RATIO TO NO. 1 STANDARD BASELINE	0 0 0	1.02% 3.00 1.26	7.46% 13.8 13.82	7.61% 18.7 15.25
TOTAL ISD DOLLARS	2,314,578 2,228,680 3,121,735	2,245,080 2,121,780 3,035,905	1,947,063 1,770,985 2,414,970	1,943,893 1,628,840 2,338,138
RATIO TO NO. 1 STANDARD BASELINE	0 0 0	3.0% 4.70 2.75	15.88% 20.5 22.64	16.02% 26.9 25.10

DETAILS OF ANALYSIS — SEE APPENDIX IV

TABLE II

AVIATION GAS TURBINE

STANDARD TYPE	1	2	3	4
ISD MANPOWER COST	1,996,434 1,765,050 2,518,370	1,975,570 1,701,565 2,491,255	1,847,185 1,473,330 2,146,615	1,844,015 1,393,620 2,052,205
RATIO TO NO. 1 STANDARD BASE	0 0 0	1.05% 3.5% 1.08	7.48% 16.5% 14.76	7.63% 21.0% 18.57
TOTAL ISD DOLLARS	2,206,934 1,990,050 2,881,370	2,138,070 1,881,565 2,803,255	1,847,185 1,518,330 2,184,115	1,844,015 1,393,620 2,052,205
RATIO TO NO. 1 STANDARD BASE	0 0 0	3.12% 5.4 2.71	16.30% 23.7 24.20	16.44% 29.9 28.78

DETAILS OF ANALYSIS - SEE APPENDIX IV

TABLE III

HEAVY DUTY GAS TURBINE

STANDARD TYPE	1	2	3	4
ISD MANPOWER COST	2,053,204 1,992,585 2,758,735	2,032,340 1,929,100 2,693,205	1,930,483 1,687,945 2,372,715	1,927,313 1,624,085 2,346,060
RATIO TO NO. 1 STANDARD BASE	0 0 0	1.02% 3.1 2.38	5.98% 15.2 13.99	6.13% 18.4 14.96
TOTAL ISD DOLLARS	2,263,704 2,217,585 3,121,735	2,192,840 2,109,100 3,005,205	1,930,483 1,732,945 2,410,250	1,927,313 1,624,085 2,346,060
RATIO TO NO. 1 STANDARD BASE	0 0 0	3.13% 4.8 3.73	14.72% 21.8 22.79	14.86% 26.7 24.85

DETAILS OF ANALYSIS - SEE APPENDIX IV

TABLE IV

SCHEDULE SAVINGS
(DAYS)

STANDARD TYPE	1	2	3	4
ESTIMATE				
1	0	32	147	147
2	0	30	120	150
3	0	34	217	242

TABLE V

AREAS OF SIGNIFICANT SAVINGS - STEAM
(IN MAN-HOURS)

FUNCTIONS ANALYZED	TYPE 1	TYPE 2	TYPE 3	TYPE 4
CONTRACT DESIGN	6,100 4,700 4,600	5,800 4,100 3,800	3,600 2,800 3,600	3,600 2,700 3,500
PROCUREMENT	16,700 24,000 19,500	15,900 20,200 18,000	10,100 11,900 13,100	10,000 11,200 12,100
DETAILED DESIGN	51,300 41,000 67,500	51,300 40,000 67,500	46,750 31,900 58,400	46,750 27,500 55,500

TABLE VI

AREAS OF SIGNIFICANT SAVINGS - DIESEL
(IN MAN-HOURS)

FUNCTIONS ANALYZED	TYPE 1	TYPE 2	TYPE 3	TYPE 4
CONTRACT DESIGN	4,700 3,500 4,300	3, 500 3,200 3,500	3,300 2,000 3,300	3,300 1,900 3,200
PROCUREMENT	12,780. 17,400 16,800	12,600 14,600 15,300	8,800 9,200 10,500	8,600 8,700 9.500
DETAILED DESIGN	38,100 29,200 60,500	38,100 :28,500 60,500	33,850 21,800 51,400	33,850 19,700 ,49,900

TABLE VII

AREAS OF SIGNIFICANT SAVINGS - <u>AVIATION GAS TURBINE</u>
(IN MAN-HOURS)

FUNCTIONS ANALYZED	TYPE 1	TYPE 2	TYPE 3	TYPE 4
CONTRACT DESIGN	4,700 3,400 4,300	3,500 3,100 3,500	3,300 2,000 3,200	3,300 2,000 3,100
PROCUREMENT	12,140 17,000 15,500	12,000 14,100 14,000	8,250 8,500 9,700	8,050 8,000 8,700
DETAILED DESIGN	38,100 28,800 57,500	38,100 28,100 57,500	33,850 22,100 43,900	33,850 19,400 42,900

TABLE VIII

AREAS OF SIGNIFICANT [illegible]INGS - HEAVY DUTY GAS TURBINE.
(IN MAN-HOURS)

FUNCTIONS ANALYZED	TYPE 1	TYPE 2	TYPE 3	TYPE 4
CONTRACT DESIGN	4,800 3,400 4,300	3,600 2,900 3,500	3,400 2,000 3,300	3,400 1,900 3,200
PROCUREMENT	13,540 17,400 16,800	13,400 14,500 14,700	9,800 9,200 10,500	9,600 8,300 9,500
DETAILED DESIGN	38,900 28,800 60,500	38,900 28,100 60,500	34,750 22,600 51,400	34,750 20,400 50,400

TABLE IX

4.4 DISCUSSION OF RESULTS

The composite of the economic results clearly shows that there is a significant potential advantage to U. S. Shipbuilders by using standards that provide a detailed description of the available, components. It is not so important that all components for the same function are the same as it is that the characteristics of all units to be considered for a function are well defined and understood by the design engineers.

The percentage savings are relatively independent of the type of power plant and are most dependent upon the type of standard selected. The savings in total ISD dollars for all types of power plants are shown in summary below. An average total savings ($\$ \times 10^{-6}$) is also tabulated.

	STANDARD TYPE 2	3	4
STEAM	2.1	14.0	14.0
	4.0	22.2	25.5
	2.5	13.4	26.2
DIESEL	3.0	15.9	16.0
	4.7	20.5	26.9
	2.8	22.6	25.1
AVIATION GT	3.1	16.3	16.4
	5.4	23.7	29.9
	2.7	24.2.	28.8
HD GT	3.1	14.7	14.9
	4.8	21.8	26.7
	3.7	22.8	24.9
AVERAGE	3.5	19.3	22.9

The development of Standard Procurement Specifications, (Standard Type No. II) indicates a minor advantage. This must be adjusted by cost of developing these specifications. It is therefore doubtful that this approach would be financially attractive.

Standard Type No. III where in a complete engineering package is available, appears to be advantageous and will result in a significant reduction of cost. The percentages indicated however, are shipyard cost savings and do not take into account the cost of specification and plan development. These costs will be "one time only" for each set of standards plus upgrading to incorporate improvements and necessary modifications. This approach is generally acceptable by the manufacturers providing that some flexibility is permitted to allow retention of manufacturing standards.

Standard Type No. IV indicates a basic shipbuilders savings of a greater proportion than No. III. This method of implementing standards includes-the specification and plans to reflect equipment suitable for use with identical interfaces met with opposition from the manufacturers because it is restrictive. The cost of converting the manufacturing procedures would offset the financial gain.

Pre-prepared specifications and plans (as in Type III) would permit the prospective owner to designate a specific propulsion plant Also the shipbuilder could readily obtain firm prices from the manufacturers.

The successful bidder could immediately release the plant for construction. The ships detail construction plans would then be developed taking into consideration the firm propulsion plant design requirements.

Rework normally required during the development of detail plans, would be minimized. Firm component dimensions would permit systematic development of the construction plans. This would reduce engineering manhours as well as provide proper guidance to the construction departments at an earlier date.

Plan approval procedures would be simplified and the normal tim span reduced. This would be both timesaving as well as reduce manhou normally expended for this purpose.

Time savings would reduce the construction period which also leads to significant savings. Various docking costs, i.e., insurance guard service, maintenance, etc. would result in major dollar saving by early delivery.

Type III standard, a complete engineering and procurement approach, has been greeted with enthusiasm by component suppliers. However most representatives believed that some funding would be required for preparation of the standard. Generally, it was felt that such a procedure would necessitate development of extensive data without assurance of receiving orders.

Type IV was generally rejected in conversation with suppliers. Some believed that new designs, castings, etc. would be required. General concern, over possible preferential treatment, was expressed. It was believed that any benefits would be negated by stagnation of design improvements on various types and sizes of standardized propulsion equipment.

It was evident that many of the vendors had prior knowledge of this study. Serious consideration had been given to the various proposals. Responses appeared to reflect the considered opinions of the manufacturers.

4.5 Vendor. Survey

Several vendors were contacted pertaining to the value of propulsion standards (See Appendix F) and, as may be expected, resulted in varied opinions. Generally, however, most manufacturers recognized some potential in each proposed method. Most agreed that standard procurement specifications (Type II) would be desirable provided the specifications were flexible enough to permit individual innovations to suit manufacturing standards.

Type III would be very useful but much effort would be required for preparation and keeping up to date.

Type IV was almost totally rejected by the suppliers as being too restrictive.

5.0 Conclusion

These studies indicate that there are potential savings in ship construction costs by the adaptation of Propulsion Standards. This is evident by the trends in the three independent studies by individuals with varied backgrounds.

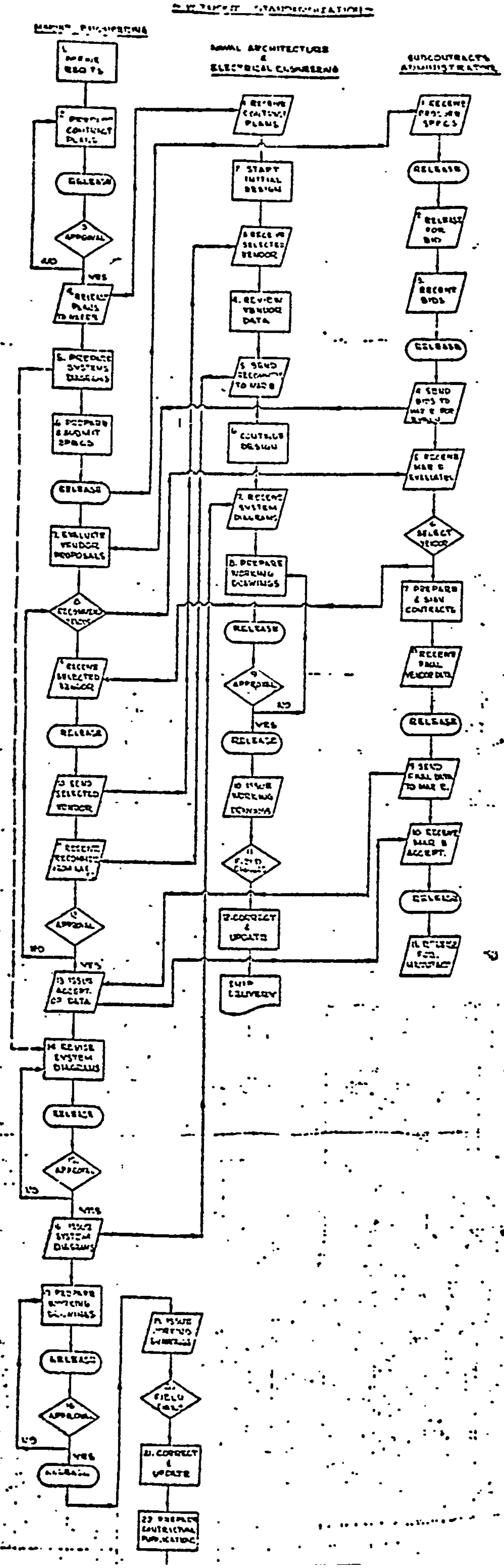
There is a parallel trend in percentage of savings for the various types of propulsion. Before actual "dollar value" can be established, more research into actual costs will be necessary. The study is based on a "one ship" effort. A multiple ship contract cannot be equated from a single ship study. There will be a decline in savings for the multiple ship case.

It should be noted that there will be a development cost fo the manufacturing standards. Although this may be costly at the time of development, it should eventually result in future savin

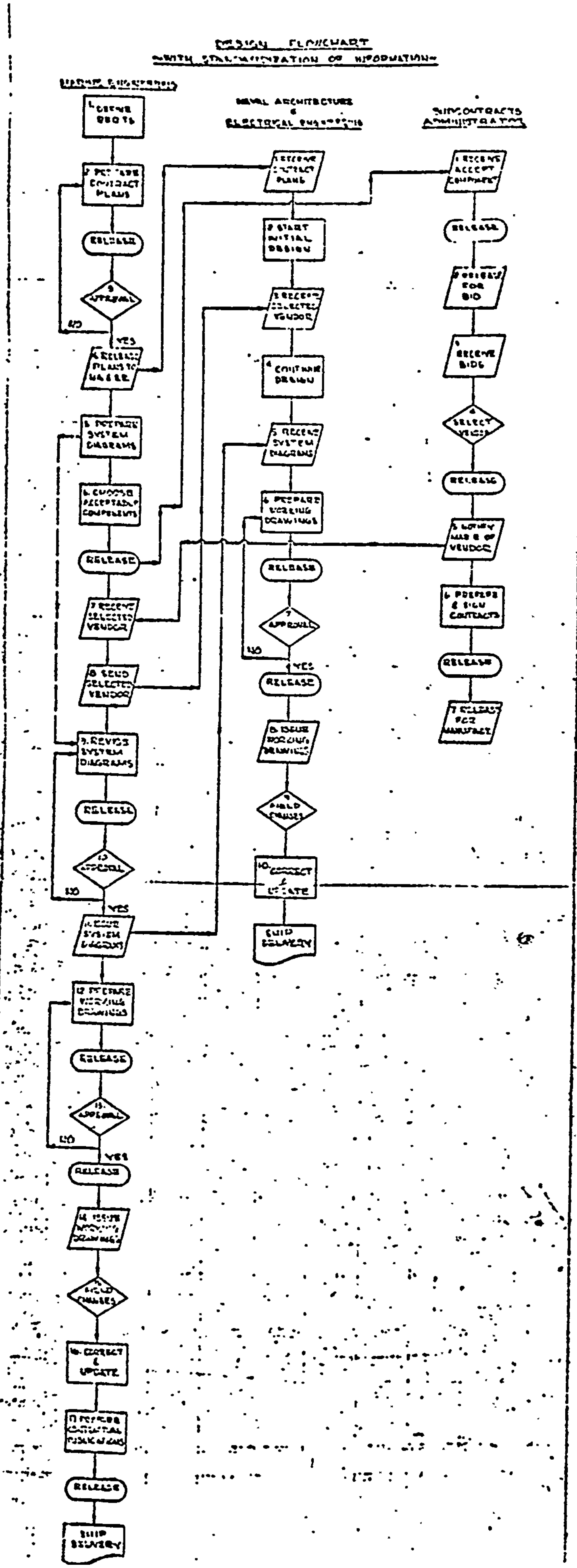
The use of standards can reduce the engineer effort. Figure 2 illustrates simplifications that can be instituted. The reducti in the steps required will speed up release and construction. This will result in major savings in maintenance, insurance, various services and docking fees. The time saved during construction will result in added revenue for the ship owner due to early ship deliveries.

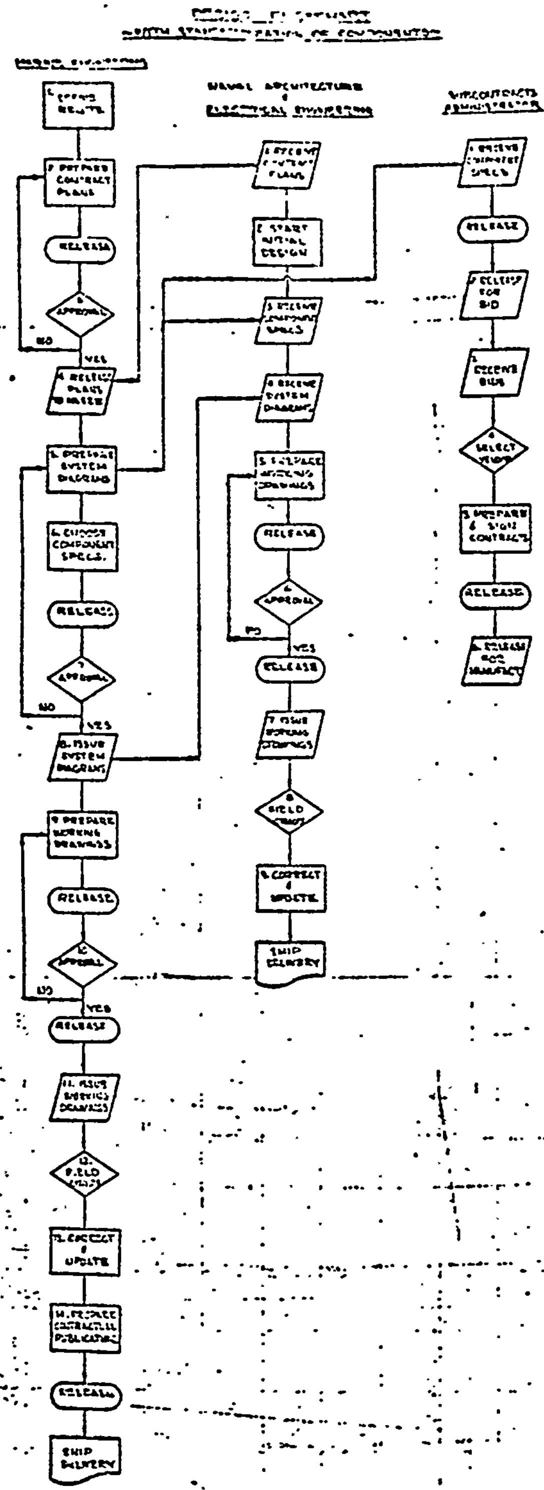
Further savings could be anticipated by development of propulsion subsystem modules. This would be a logical step once the equipment is developed in a standard form.

Standard propulsion packages would permit early development o basic hull design. Machinery spaces would be arranged to accommodate the propulsion packages during the early stages of design effort. They would be assembled by suppliers specializing



NAVAL ARCHITECTURE
&
ELECTRICAL ENGINEERING
SUBCONTRACTS ADMINISTRATION
7 START INITIAL DESIGN
RELEASE
APPROVAL
YES
NO
6 SELECT VENDOR
7 PREPARE & SIGN CONTRACTS
SHIP DELIVERY


DESIGN FLOWCHART
START INITIAL DESIGN
CONTINUE DESIGN
RECEIVE BIDS
SELECT VENDOR
RELEASE
YES
NO
CORRECT & UPDATE
SHIP DELIVERY


NAVAL ARCHITECTURE
RELEASE
APPROVAL
YES
NO
SHIP DELIVERY

6.0 RECOMMENDATIONS

1. Survey all manufacturers to determine the cost of producing standard design packages. Consider, also the cost of obtaining approval, of standards, from the various regulatory bodies.

20 Extend the study effort into various classes of ships. Suitable horsepowers of the four methods of propulsion should be selected.

3. Review and compile all data. Reduce the findings to a usable form and circulate to all interested parties for application.

4. Prepare some standards for several power plants that are most useful and apply them in actual practice to test their utility.

APPENDICES

A. MEMO OF UNDERSTANDING

B. MACHINERY PLANT DESCRIPTION DATA

C. ECONOMIC ANALYSIS SHEETS

D. ECONOMIC POWER PLANT TRADEOFFS

E. LIST OF DRAWINGS AND SPECIFICATIONS

F. COMMENTS FROM SUPPLIERS

APPENDIX A

MEMO OF UNDERSTANDING

APPENDIX A

- AGREEMENT -

MEMO OF UNDERSTANDING

INTERPRETATION OF PROPULSION STANDARDS PROGRAM
WORK STATEMENT

It is understood that Ingalls Shipbuilding will carry out the following tasks as an interpretation of the Propulsion Standards proposal dated 14 June 1974.

(1) Define and layout 4 propulsion plants for a 150,000 dwt tanker including steam, medium speed diesel, heavy duty gas turbine and aircraft derivative gas turbine plant.

(2) Define ~~two~~ three levels of standards applied to the components of the 4 propulsion plants listed above: (1) one that is a full description of the component by a data package that is unique each to vendor's component, ~~and~~ (2) another standard that is an interface and performance specification applicable for all components of a given size range and (3) another is a standard procurement specification

(3) Evaluate the cost differential to Ingalls Shipbuilding by the application of the two levels of standards described above to the propulsion plant to the 150,000 dwt tanker.

The economic analysis will include the effect on engineering man-hours, production man-hours, and procurement related costs.

(4) Contact informally 6 to 8 suppliers of key propulsion components to solicit information on (a) the merits of the two types of proposed standards, (b) the acceptability of the two proposed types of standards, (c) approximate costs of developing the data type of standard.

(5) Review and comment on Rosenblatt selections and definitions of Propulsion Standards prepared as a part of their BIW study.

(6) Prepare a report covering the results of the 5 tasks itemized above.

R. FORD
BATH IRON WORKS

F. KOSOFSKY
INGALLS SHIPBUILDING

APPENDIX B

MACHINERY PLANT DESCRIPTION DATA

ENGINEERING TECHNICAL NOTE #1

FOUR POWER PLANT DESIGNS
FOR A
150,000 DWT TANKER

R. A. LEVINE, D. A. RAINS, H. T. CHEYNE,
AND J. R. DENSON

TN-1

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FOUR POWER PLANT DESIGNS FOR A 150,000 DWT TANKER

ABSTRACT

This note summarizes a description of the four power plant designs that are being done for the Maritime Administration funded "Power Plant Standardization Feasibility Study". The four power plants that were chosen are; steam, lightweight gas turbine, heavy duty gas turbine and medium speed diesels.

Preliminary analysis to determine which power plants were suitable for the 150,000 DWT tanker was done in Reference 1), Reference 2), and Reference 3). These studies indicated that lightweight gas turbines, heavy duty gas turbine and medium speed diesels were the most ideally suited. Steam was added for comparison purposes.

CHARACTERISTICS

CARGO CAPACITY	-	150,000 DWT	
RANGE		12,000 NAUTICAL MILES	
SPEED		16 KNOTS	
HORSEPOWER		25,000 SHP	
FUEL		VARIABLE	
PROPELLER		32' DIAMETER	4 BLADES
SHAFTING		TAILSHAFT	29.333" Dia.
		LINESHAFT	23.732" Dia.

DESCRIPTION OF MACHINERY

A. BASIC PHILOSOPHY

1. Unmanned Machinery Space - The propulsion plants are to be fully automated, with bridge control, to facilitate a completely unattended engine room.

2. Simplicity of Installation - The propulsion plants, turbines and gear, and diesel and gear are to be hard-mounted on a common bedplate and then hard mounted on the ship. Packaging of service components into modules will be utilized as much as possible. An example of the use of this type of installation may be in the packaging of the fuel oil service system into a module. The components of the module woild be the fuel oil transfer pumps, fuel oil filters and the fuel oil strainers.

3. Maximum Utilization of Space - The engine room space is to be of minimum volume to provide as much extra cargo space as possible. Bulkhead locations are to remain in the same position, if possible, for the different power plants so that the same basic ship arrangements can be used despite the particular plant. To reduce fabrication costs fuel storage will be done in double bottom tanks and in full breadth tanks located within the engine room, just aft of the forward engine room bulkhead. No wing tanks are be used.

B. DESCRIPTIONS

1. Systems Diagrams - Diagrams showing schematic presentation of various systems can be found in the following figures:

Steam

Fig. 1 Main Steam System
Fig. 2 High Pressure Feed System
Fig. 3 Sea Water Circ. System
Fig. 4 Fuel Oil Service System
Fig. 5 Diesel Oil Service System
Fig. 6 Lube Oil System

Lightweight Gas Turbine

Fig. 7 Fuel Oil System
Fig. 8 Lube Oil System
Fig. 9 Sea Water Cooling System
Fig. 10 Start Air System

Heavy Duty Gas Turbine

Fig. 11 Fuel Oil System
Fig. 12 Lube Oil System
Fig. 13 Sea Water Cooling System

Medium Speed Diesel

Fig. 14 Fuel and Diesel Oil Service System
Fig. 15 Fuel and Diesel Oil Transfer System
Fig. 16 Lube Oil System
Fig. 17 Start Air and Control Air System

2. Equipment Lists - Lists of equipment that are required can be found in the following tables:

   Table 1. Steam Machinery List

   Table 2. Lightweight Gas Turbine Machinery List

   Table 3. Heavy Duty Gas Turbine Machinery List

   Table 4. Heavy Duty Gas Turbine Machinery List

3. Arrangement Drawings - Machinery arrangement drawings have been prepared for this tanker. They are shown in the following figures:

   Figure 18 Steam Machinery Arrangements
   Plan No. PSE-8199-1S40-0-1

   Figure 19 Lightweight Gas Turbine Machinery Arrangements
   Plan No. PSE-8199-2S40-0-1

   Figure 20 Heavy Duty Gas Turbine Machinery Arrangement
   Plan No. PSE-8199-3S40-0-1

   Figure 21 Medium Speed Diesel Machinery Arrangement
   Plan No. PSE-8199-4S40-0-1

4. <u>Vendor Data</u> - Vendor data concerning some of the major components can be found in the following tables:

   Table 5 Steam
   Table 6 Lightweight Gas Turbine
   Table 7 Heavy Duty Gas Turbine
   Table 8 Medium Speed Diesel

5. <u>Alternative Designs</u> - The use of a ducted propeller as a possible alternative, for the reduction in size and an increase in efficiency. This alternative is discussed fully in Reference 4) and is illustrated in Figure 19.

CONCLUSIONS

Four viable, compact, efficient power plants for a 150,000 DWT tanker are described. Since only the description of the power plants was required, for the standardization feasibility study, no effort was made to evaluate the merits of the different plants. Preliminary economic comparisons were made in References 1), 2), 3). Should a more detailed comparison be required this study will serve as an excellent basis for such an effort.

References:

1) TN-7A; B. T. Jeavons, D. A. Rains, & H. T. Cheyne, "A Propulsion Plant Comparison for 120,000 DWT Tanker"

2) TN-8; D. A. Rains "Steam Generation System Evaluation for a 120,000 DWT Tanker"

3) TN-25; R. A. Levine, D. A. Rains & H. T. Cheyne "120,000 DWT Tanker Machinery Design Status Report"

4) TN-20 "Ducted Propeller Applied to the 120,000 DWT Tanker" by D. A. Rains

TABLE 1.

STEAM PROPULSION PLANT & AUXILIARY MACHINERY LIST

	DESCRIPTION	QTY.
1.	H.P. TURBINE	1
2.	L.P. TURBINE	1
3.	REDUCTION GEAR	1
4.	THRUST BEARING	1
5.	LINE SHAFT BEARING	
6.	SHAFTING	1 Set
7.	STERN TUBE & BEARING	1
8.	STERN TUBE SEALS (Inboard & Outboard)	1 Each
9.	PROPELLER (Fixed Pitch)	1
10.	MAIN CONDENSER	1
11.	MAIN CIRC. PUMP	1
12.	VACUUM PUMP	1
13.	LUBE OIL COOLER	1
14.	LUBE OIL PUMPS	1
15.	LUBE OIL FILTER	1
16.	LUBE OIL PURIFIER	1
17.	LUBE OIL HEATER	1
18.	MAIN BOILERS	2
19.	MAIN FEED PUMPS	2
20.	EMERGENCY FEED PUMP	1
21.	DFT	1
22.	COMBINATION 1St STAGE FEED HEATER, GLAND EXH. CONDENSER AND DRAIN COOLER	1
23.	THIRD AND FOURTH STAGE HP FEED HEATER	1
24.	EXHAUSTER GLAND LEAKOFF	1
25.	FEED SAMPLE COOLER	1
26.	BOILER AIR HEATER	1
27.	FORCED DRAFT FANS	2
28.	PRIMING PUMP	1
29.	F.O. SERVICE PUMP	1
30.	F.O. TRANSFER PUMP	1
31.	F.O. FILTER COALESCER	1
32.	F.O. HEATER	

TABLE 1. (CONT'D.)

STEAM PROPULSION PLANT & AUXILIARY MACHINERY LIST

	DESCRIPTION	QTY.
33.	SHIPS SERVICE AIR COMPRESSORS	2
34.	SHIPS SERVICE AIR RECEIVERS	5
35.	EMERGENCY AIR COMPRESSOR	1
36.	EMERGENCY AIR RECEIVER	1
37.	DISTILLING PLANT	1
38.	DISTILLING PLANT SW FEED PUMP	1
39.	DISTILLING PLANT BRINE PUMP OVERBOARD DISCH.	1
40.	TANK CLEANING SW HEATER & DRAIN COOLER	1
41.	SHIPS SERVICE TURBO GENERATOR	2
42.	EMERGENCY DIESEL GENERATOR	1
43.	DIESEL OIL FILTER COALESCER	1
44.	DIESEL GEN LUBE OIL COALESCER	1
45.	DOMESTIC WATER HEATER & TANK	1
46.	BILGE PUMPS	2
47.	FIRE PUMPS	2
48.	DOMESTIC WATER PUMPS	2
49.	SW SERVICE PUMP	1
50.	TANK CLEANING PUMP	1
51.	ATMOSPHERIC DRAIN PUMP	1
52.	PURIFIER WATER PUMP	1
53.	OBSERVATION DRAIN TANK	1
54.	FEED & CONDENSATE DRAIN TANK	1
55.	CONDENSATE PUMPS	2
56.	SEWAGE TREATMENT PLANT	1
57.	POTABLE & SANITARY PUMPS	2
58.	HOT WATER CIRC PUMP	1
59.	L.O. STORAGE TANKS	
60.	DIESEL GEN FO DAY TANK	1

TABLE 2.
LIGHTWEIGHT GAS TURBINE
PROPULSION PLANT & AUXILIARY MACHINERY LIST

	DESCRIPTION	QTY.
1.	MAIN ENGINES GT LM 2500X	1
2.	REDUCTION GEAR (REVERSING)	1
3.	THRUST BEARING	1
4.	LINE SHAFT BEARING	
5.	SHAFTING	1 Set
6.	STERN TUBE & BEARING	1
7.	STERN TUBE SEALS (Inboard & Outboard)	1 Each
8.	PROPELLER (Fixed Pitch)	1
9.	TAKE HOME MOTOR (2000 HP)	1
10.	SHIPS SERVICE AIR COMPRESSOR	2
11.	SHIPS SERVICE AIR RECEIVER	5
12.	FO SERVICE PUMPS	1
13.	FO FILTER	1
14.	FO STRAINER	1
15.	FO TRANSFER PUMP	1
16.	DIESEL OIL TRANS PUMP	1
17.	LO SERVICE PUMPS	2
18.	LO TRANSFER PUMP	1
19.	LO SUMP TANK	1
20.	LO FILTER	1
21.	LO PURIFIER	1
22.	LO HEATER	1
23.	SW COOLING PUMPS	2
24.	SW STRAINER	2
25.	AIR INLET DEMISTER	
26.	AIR INLET SILENCER	
27.	EXHAUST SILENCER (ME)	
28.	EXPANSION JOINTS EXHAUST SYSTEM ME	
29.	WASTE HEAT BOILER	1
30.	BOILER FEED PUMP	1
31.	BOILER FEED WATER SAMPLE COOLER	1
32.	FO SERVICE TANKS	
33.	DIESEL OIL TANKS	

TABLE 2. (CONT'D.)

LIGHTWEIGHT GAS TURBINE
PROPULSION PLANT & AUXILIARY MACHINERY LIST

	DESCRIPTION	QTY.
34.	WATER WASH PROPORTIONING UNIT	1
35.	DISTILLING PLANT	2
36.	DISTILLING PLANT SW FEED PUMP	2
37.	DISTILLING PLANT BRINE PUMP OVERBD DISCH.	2
38.	OBSERVATION DRAIN TANK	1
39.	FEED AND CONDENSATE DRAIN TANK	1
40.	SEWAGE TREATMENT PLANT	1
41.	POTABLE & SANITARY WATER PUMPS	2
42.	HOT WATER CIRC. PUMP	1
43.	BILGE PUMPS	2
44.	FIRE PUMPS	2
45.	SHIPS SERVICE DIESEL GENERATOR	2
46.	SHIPS SERVICE DIESEL GEN EXH. SILENCER	2
47.	EMERGENCY DIESEL GEN.	1
48.	EMERGENCY DIESEL GEN. EXH. SILENCER	1
49.	SLUDGE PUMP	1
50.	POTABLE HOT WATER HEATER	1
51.	POTABLE WATER STORAGE TANK	1
52.	S/S GEN DO DAY TANK	1
53.	EMERGENCY GEN DO DAY TANK	1
54.	DIESEL OIL STORAGE TANK	
55.	LUBE OIL STORAGE TANKS	

TABLE 3.

HEAVY DUTY GAS TURBINE
PROPULSION PLANT & AUXILIARY MACHINERY LIST

	DESCRIPTION	QTY.
1.	MAIN ENGINES H/D GAS TURBINE	1
2.	REGENERATOR & PIPING	1
3.	REDUCTION GEAR	1
4.	THRUST BEARING	1
5.	LINE SHAFT BEARING	
6.	SHAFTING	1 Set
7.	STERN TUBE & BEARING	1
8.	STERN TUBE & SEALS(Inboard & Outboard)	1 Each
9.	PROPELLER (Fixed Pitch)	1
10.	SHIP SERVICE AIR COMPRESSOR	2
11.	SHIP SERVICE AIR RECEIVERS	5
12.	AIR INLET DEMISTER	
13.	AIR INLET SILENCER	
14.	EXHAUST SILENCER (ME)	1
15.	EXHAUST SYSTEM EXPANSION JOINTS (ME)	
16.	HEAVY FUEL OIL FORWARDING UNIT	1
17.	DISTILLATE FORWARDING UNIT	1
18.	FUEL FILTER TRANSFER UNIT	1
19.	HEAVY FUEL ANALYSIS UNIT	1
20.	FUEL WASHING UNIT	1
21.	WATER WASH PROPORTIONING UNIT	1
22.	DE-EMULSIFICATION UNIT	1
23.	FUEL PROCESSING CONTROL UNIT	1
24.	F.O. SERVICE BOOST PUMP	1
25.	F.O. TRANSFER PUMP	1
26.	F.O. SERVICE TANK	1
27.	L.O. SERVICE PUMP	1
28.	L.O. COOLER	1
29.	L.O. TRANSFER PUMP	1
30.	L.O. PURIFIER	1
31.	L.O. HEATER	1
32.	L.O. SUMP TANK	1
33.	SLUDGE PUMP	

TABLE 3. (CONT'D.)

HEAVY DUTY GAS TURBINE
PROPULSION PLANT & AUXILIARY MACHINERY LIST

	DESCRIPTION	QTY.
34.	SW COOLING PUMPS	2
35.	SW STRAINER	2
36.	OIL FIRED BOILER	1
37.	BOILER FEED PUMP	1
38.	BOILER WATER SAMPLE COOLER	1
39.	BOILER EXPANSION TANK	1
40.	BOILER CHEM MIXING TANK	1
41.	RESERVE FEED TANK	1
42.	OBSERVATION DRAIN TANK	1
43.	FEED AND CONDENSATE DRAIN TANK	1
44.	DISTILLING PLANT	1
45.	DISTILLING PLANT SW FEED PUMP	1
46.	DISTILLING PLANT BRINE PUMP OVERBD DISCH.	1
47.	SHIPS SERVICE DIESEL GENERATOR	1
48.	SHIPS SERVICE DIESEL GEN. EXH. SILENCER	1
49.	EMERGENCY DIESEL GEN.	1
50.	EMERGENCY DIESEL GEN EXHAUST SILENCER	1
51.	S/S GEN DO DAY TANK	1
52.	EMERGENCY GENERATOR DAY TANK	1
53.	DIESEL OIL TRANSFER PUMP	1
54.	DIESEL START AIR SYS.	1
55.	LUBE OIL STORAGE TANKS	1
56.	DIESEL OIL STORAGE TANKS	1
57.	SEWAGE TREATMENT PLANT	1
58.	POTABLE, SANITARY WATER PUMPS	2
59.	HOT WATER CIRC PUMP	1
60.	BILGE PUMPS	2
61.	FIRE PUMPS	2

TABLE 4.

MEDIUM SPEED DIESEL
PROPULSION PLANT & AUXILIARY MACHINERY LIST

	DESCRIPTION	QTY.
1.	MAIN ENGINES	2
2.	REDUCTION GEAR	1
3.	THRUST BEARING	1
4.	LINE SHAFT BEARING	
5.	SHAFTING	1 Set
6.	STERN TUBE & BEARING	1
7.	STERN TUBE SEALS (Inboard & Outboard)	1 Each
8.	PROPELLER (Fixed Pitch)	1
9.	SHIPS SERVICE AIR COMPRESSORS	2
10.	SHIP SERVICE AIR RECEIVERS	6
11.	MAIN SW CIRC PUMP	1
12.	AUX. SW CIRC PUMP	1
13.	ME JACKET WATER COOLER	2
14.	ME JACKET CW EXPANSION TANK	1
15.	PISTON CW TANK	1
16.	ME LUBE OIL COOLER	2
17.	ME STANDBY LUBE OIL PUMPS	2
18.	LUBE OIL STORAGE TANK	1
19.	LUBE OIL PURIFIER	1
20.	LUBE OIL HEATER	1
21.	LUBE OIL FILTER	1
22.	LUBE OIL STORAGE TANKS	
23.	LUBE OIL TRANSFER PUMP	1
24.	FUEL OIL SERVICE PUMP (BOOST)	2
25.	ME FUEL OIL PREHEATER	1
26.	ME FUEL OIL RETURN TANK	1
27.	ME FUEL OIL FILTER	2
28.	FUEL OIL TRANSFER PUMP (ME)	1
29.	HEAVY OIL TRANSFER PUMP	1
30.	HEAVY OIL PREHEATER	1
31.	OIL FIRED BOILER	1
32.	BOILER FEED PUMP	1

TABLE 4. (CONT'D)

MEDIUM SPEED DIESEL
PROPULSION PLANT & AUXILIARY MACHINERY LIST

	DESCRIPTION	QTY.
33.	BOILER EXPANSION TANK	1
34.	BOILER CHEM. MIXING TANK	1
35.	BOILER FEED WATER SAMPLE COOLER	1
36.	RESERVE FEED TANK	1
37.	DISTILLING PLANT	1
38.	DISTILLING PLANT S.W. FEED PUMP	1
39.	DISTILLING PLANT BRINE PUMP OVERBD. DISCH.	1
40.	SHIP SERVICE DIESEL GENERATORS	2
41.	SHIP SERVICE EXHAUST SILENCER	2
42.	EMERGENCY GENERATOR SET	1
43.	EMERGENCY GENERATOR EXHAUST SILENCER	1
44.	SHIPS SERVICE GEN DO DAY TANK	1
45.	EMERGENCY GENERATOR FO DAY TANK	1
46.	DIESEL START AIR SYSTEM	2
47.	SEWAGE TREATMENT PLANT	2
48.	BILGE PUMPS	2
49.	FIRE PUMPS	2
50.	OBSERVATION DRAIN TANK	1
51.	FEED & CONDENSATE DRAIN TANK	1
52.	POTABLE & SANITARY WATER PUMPS	2
53.	HOT WATER CIRC. PUMP	1
54.	SLUDGE PUMP	1
55.	DIESEL OIL TRANSFER PUMP	1

TABLE 5.

STEAM
(BASED ON APL-FARRELL)

BOILER

MANUFACTURER	COMBUSTION ENGINEERING
NUMBER	2
TYPE	SINGLE FURNACE, SINGLE UPTAKE, SIDE FIRST

PERFORMANCE (EACH) BOILER	NORMAL	OVERLOAD
SUPERHEATED STEAM, LBS/HR	87,200	104,800
SUPERHEATER OUTLET PRESSURE, PSIG	870	857
SUPERHEATER OUTLET TEMP, °F	955	955
DRUM DESIGN PRESSURE, PSIG	1,050	1,050
FEED TEMPERATURE, °F	408	350
GUARANTEED EFFICIENCY, %	89	88.5
DRAFT LOSS, IN. H_2O	13	19.41
HEAT RELEASE RATE, BTU/HR/CU. FT.	70,000	90,000

TURBINES

MANUFACTURER	WESTINGHOUSE ELECTRIC CO.
NUMBER PER SHIP	1
TYPE	HIGH SPEED, CROSS COMPOUND, H.P. AND L.P., GEARED

NORMAL AHEAD POWER, SHP	26,000
MAX. CONTINUOUS AHEAD, SHP	28,500
ASTERN POWER @ 27.5 IN. Hg.VAC,SHP	21,375
TURBINE INLET STEAM PRESSURE, PSIG	850
TURBINE INLET STEAM TEMP., °F	950
EXHAUST VACUUM (AHEAD) IN. Hg.	28.5
TOTAL NUMBER OF EXTRACTIONS	4
EXHAUST VACUUM (ASTERN), IN. Hg.	27.5
GUARANTEED STEAM RATE @ NORMAL LOAD, NON-EXTRACTING LBS/SHP-HR	5.50

	PSIA	LB/HR
FIRST H.P. EXTRACTION	332	10,982
SECOND H.P. EXTRACTION	176	11,175
CROSSOVER EXTRACTION	72.9	6,189
L.P. EXTRACTION	11.2	15,074

TABLE 5. (CONT'D)

MAIN PROPULSION GEAR

MANUFACTURER	WESTINGHOUSE ELECTRIC CO.
NO. PER SHIP	1
TYPE	ARTICULATED DOUBLE REDUCTION, DOUBLE HELICAL
NORMAL PROPELLER SPEED, RPM	103
MAX. CONTINUOUS PROPELLER SPEED, RPM	106.5
TURNING GEAR MOTOR RATING, HP	10
SHAFT TURNING GEAR SPEED	1 REV. IN 10 MIN.
MAXIMUM "K" FACTOR	
FIRST REDUCTION	140
SECOND REDUCTION	110

TABLE 6.
LIGHTWEIGHT GAS TURBINE

GAS TURBINE	
MANUFACTURER	GENERAL ELECTRIC CO.
NUMBER	1
TYPE	LM-2500-X Supercharged
RATED	25,000 SHP @ 80°F Inlet Air
TAKE HOME POWER	2000 HP - AC Motor
SPEED	6.9 KNOTS
REDUCTION GEAR	
MANUFACTURER	WESTINGHOUSE ELECTRIC CO.
NUMBER	1
TYPE	ARTICULATED, DOUBLE REDUCTION, DOUBLE HELICAL, REVERSING NO. NM-23
REDUCTION RATIO	44.9421 (Ahead) 45.5127 (Astern)
WEIGHT - GEAR Thrust Brg.	220,000 Lbs 54,000 Lbs
	274,000 Lbs
MAXIMUM "K" FACTOR	
FIRST REDUCTION	140
SECOND REDUCTION	110
WASTE HEAT BOILER	
MANUFACTURER	COMBUSTION ENGINEERING
NUMBER	1
BOILER PERFORMANCE	
DRUM PRESSURE -	150 PSIG
FEED WATER TEMP.	120°F
TOTAL EVAPORATION	59,500 Lb/Hr
GAS TEMP. ENTERING BOILER	925°F
GAS TEMP. LEAVING BOILER	450°F
TOTAL DRAFT LOSS	3.6 In. H.g.

TABLE 7.

HEAVY DUTY GAS TURBINE

GAS TURBINE AND REDUCTION GEAR

MANUFACTURER	GENERAL ELECTRIC	
NUMBER	1	
TYPE	MODEL MM5002R-B FRAME 5 REGENERATIVE GAS TURBINE	
PERFORMANCE	RESIDUAL FUEL	DISTILLATE
OUTPUT SHP	26,900	28,700
SPECIFIC FUEL CONSUMPTION Lb/Shp-Hr	0.459	0.427
AIR FLOW Lb/Hr	916,000	

Ratings @ 59°F Ambient, 3" H_2O Inlet Pressure Drop, 5" H_2O Exhaust Pressure Drop, 14.7 psia Ambient and a Reduction Gear Efficiency of 98%

Weights (Lbs)

TURBINE AND BASE	213,000
REGENERATOR	250,000
REDUCTION GEAR	160,000
THRUST BEARING	38,000
	661,000

SHIP SERVICE STEAM

BY STEAM GENERATOR

TABLE 8.

MEDIUM SPEED DIESEL

MEDIUM SPEED DIESEL

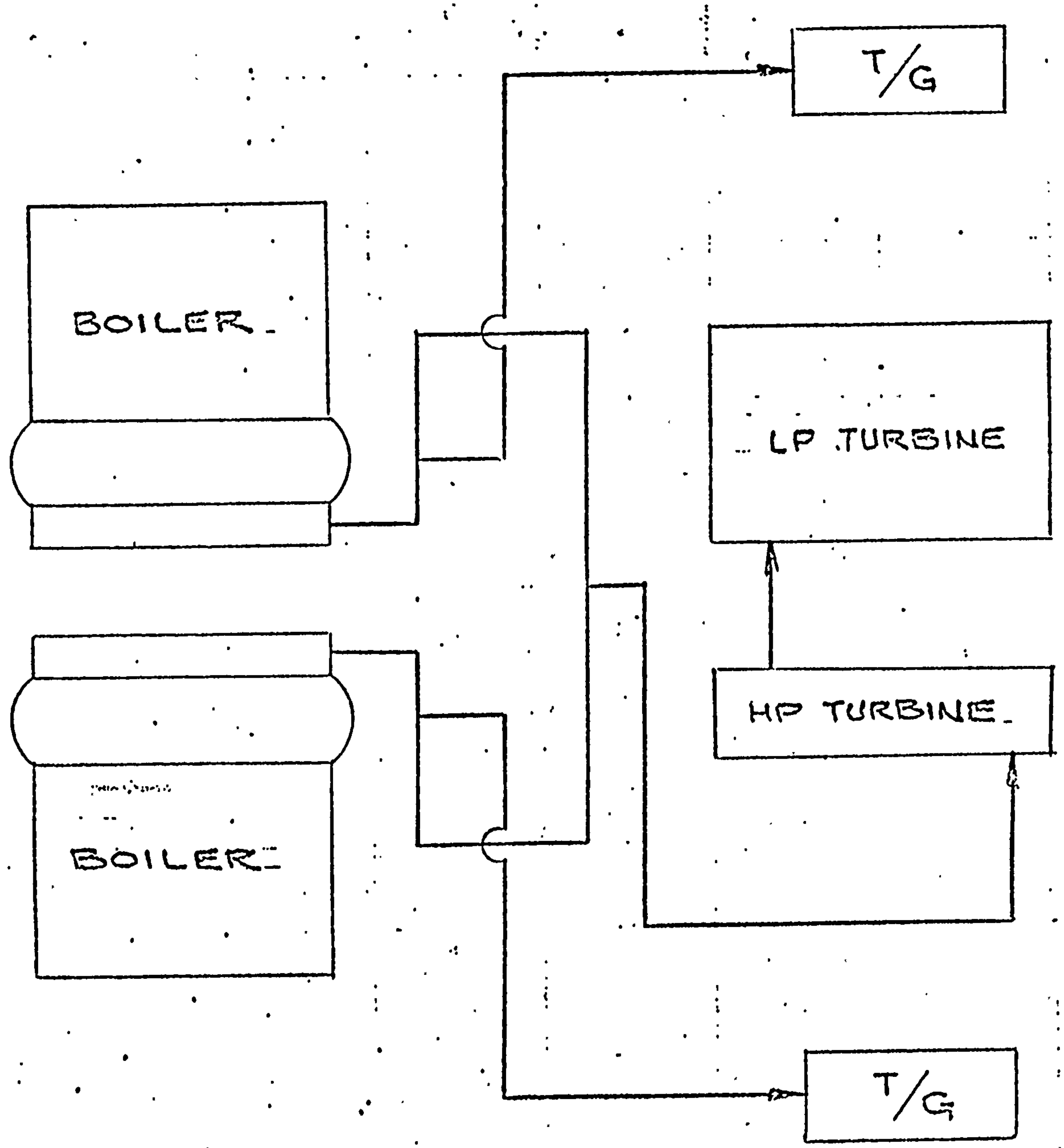
MANUFACTURER	DELAVAL ENTERPRISE
NUMBER	2
TYPE	DMRV-20-4, TURBOCHARGED INTERCOOLE SOLID INJECTION, 4 CYCLE, REVERSIN
RATED	12,500 BHP
RPM	450
BMEP	231
CYLINDERS	20
BORE	17"
STROKE	21"
DISPLACEMENT	95,332 Cu. Ni.
PISTON SPEED	1575 Ft. Per Min.
FUEL	No. 2 or Heavy Fuels Up to 3600 Redwood No. 1 Seconds at 100°F

REDUCTION GEAR

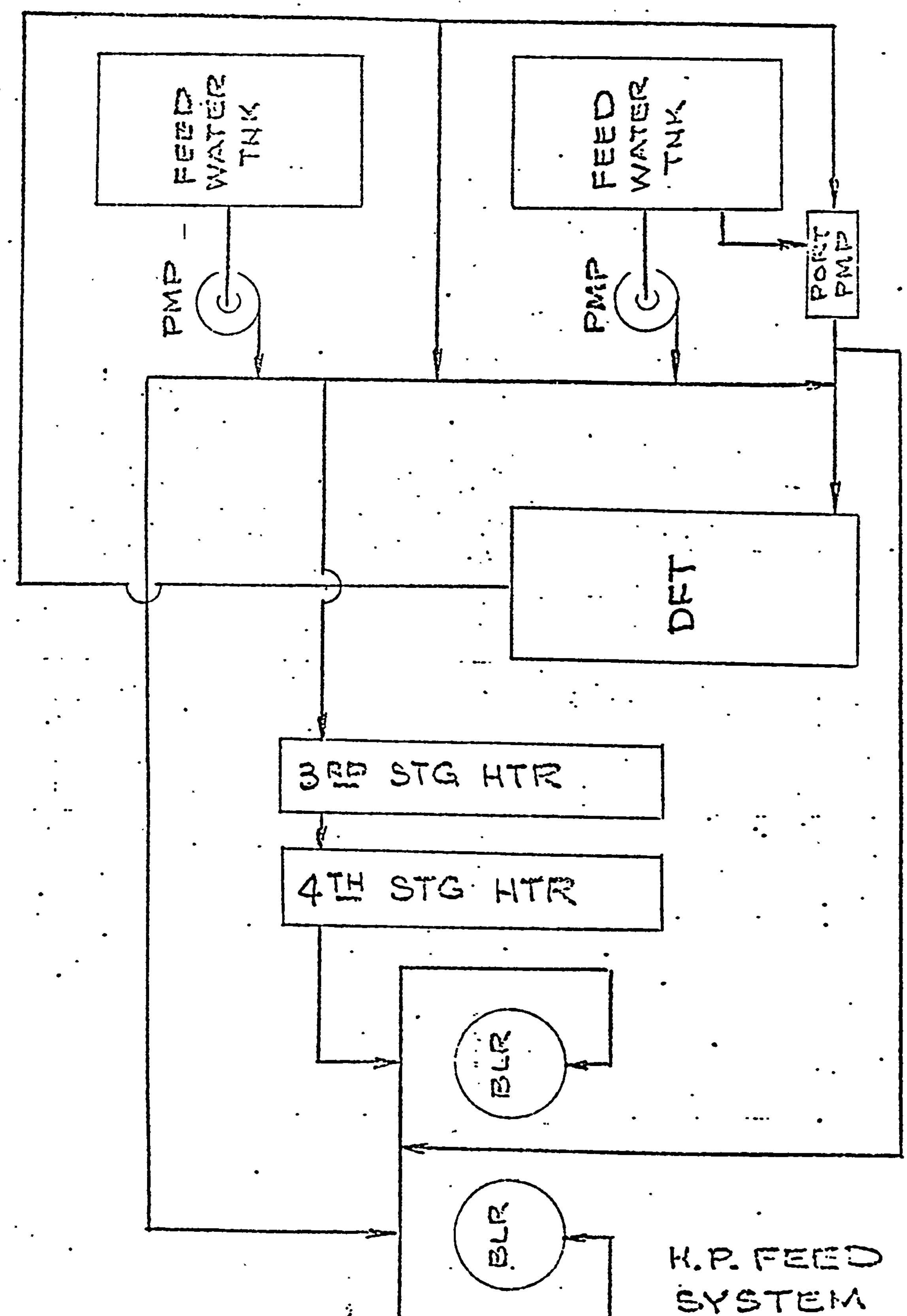
Purchased with Engines Double Input - Single Output
450 to 120 RPM Reduction

SHIP SERVICE STEAM

By Steam Generator



MAIN STEAM
SYSTEM


FEED WATER TNK
PMP
FEED WATER TNK
PMP
PORT PMP
DFT
3RD STG HTR
4TH STG HTR
BLR
BLR
H.P. FEED SYSTEM

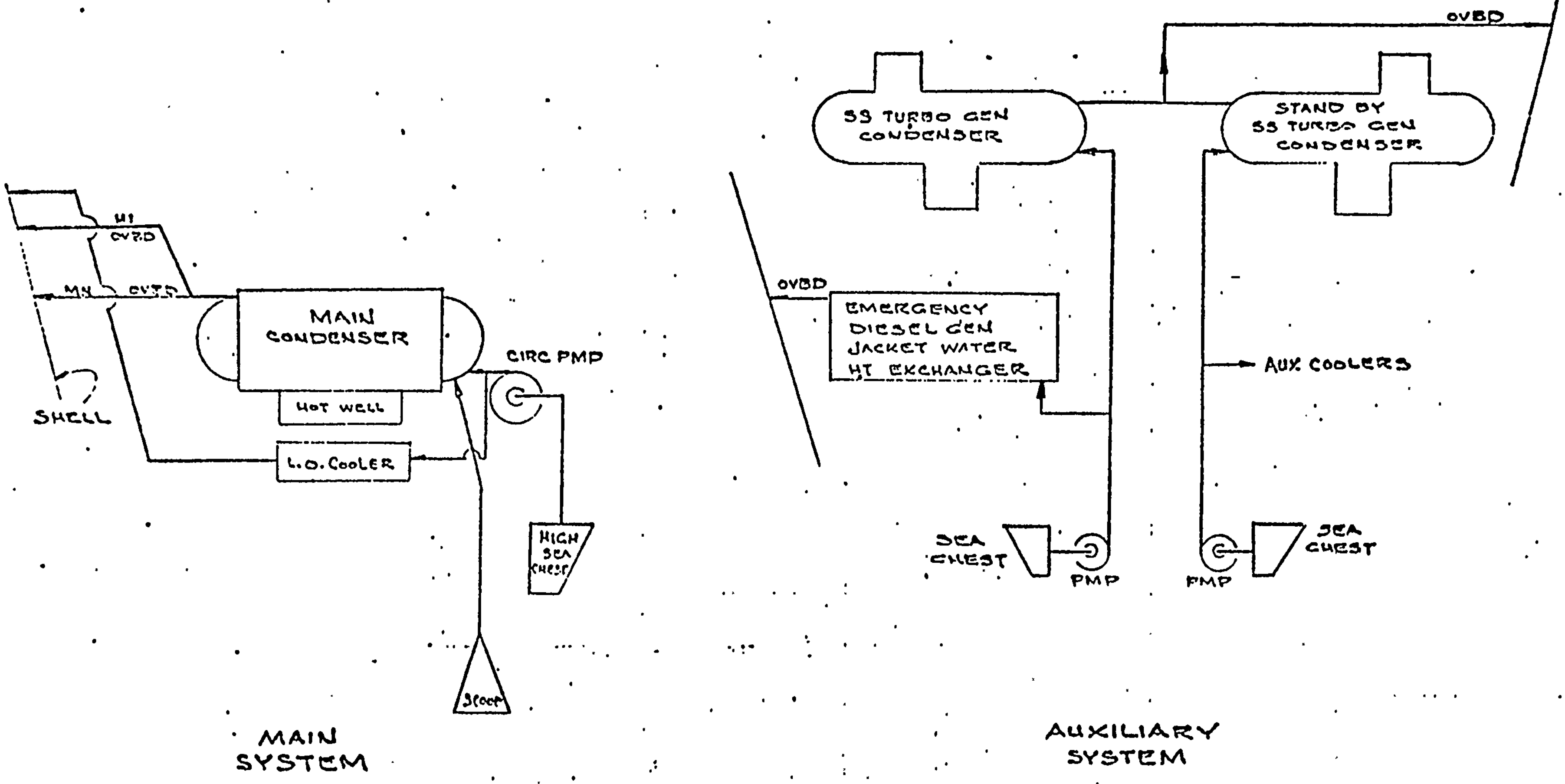
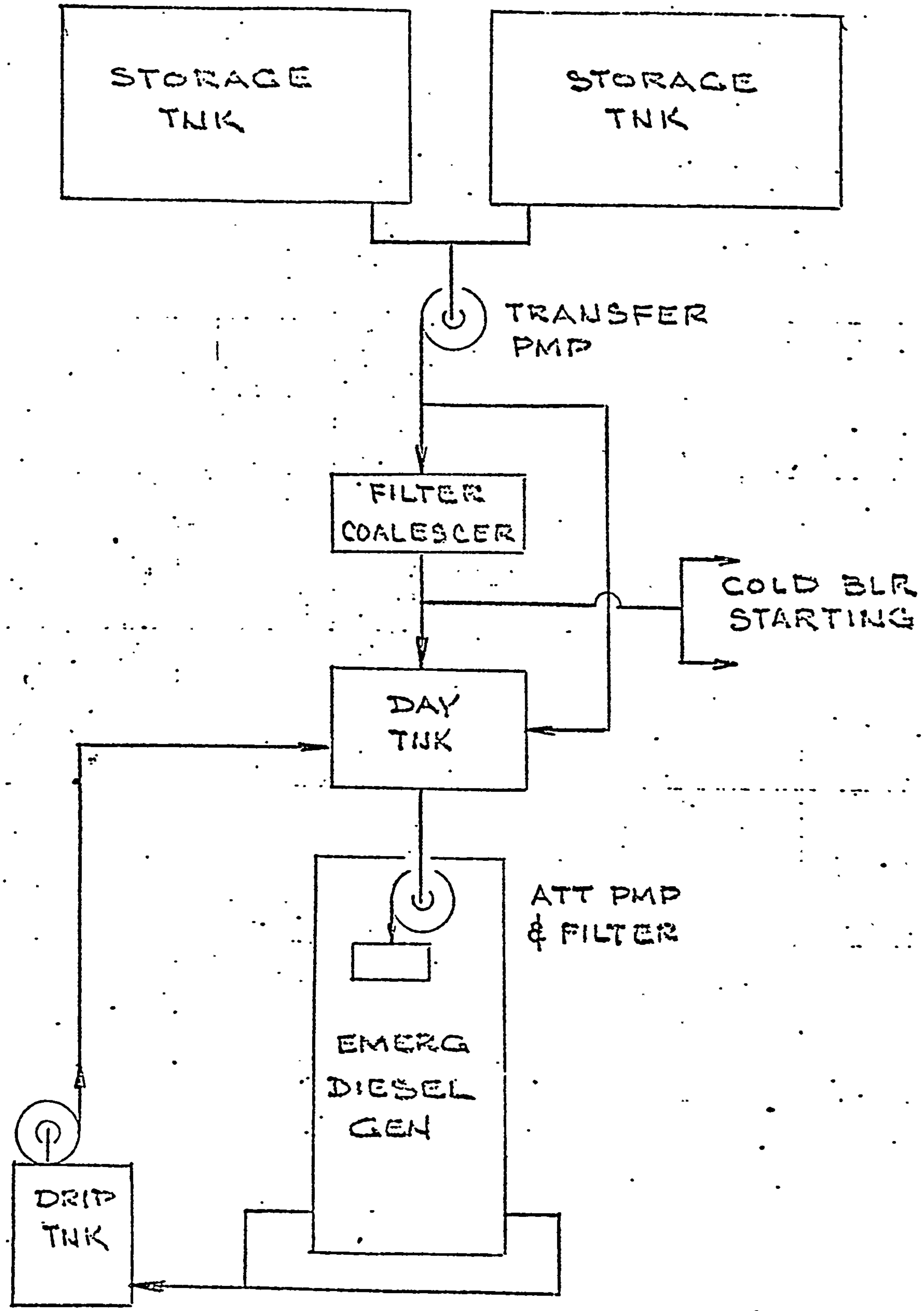
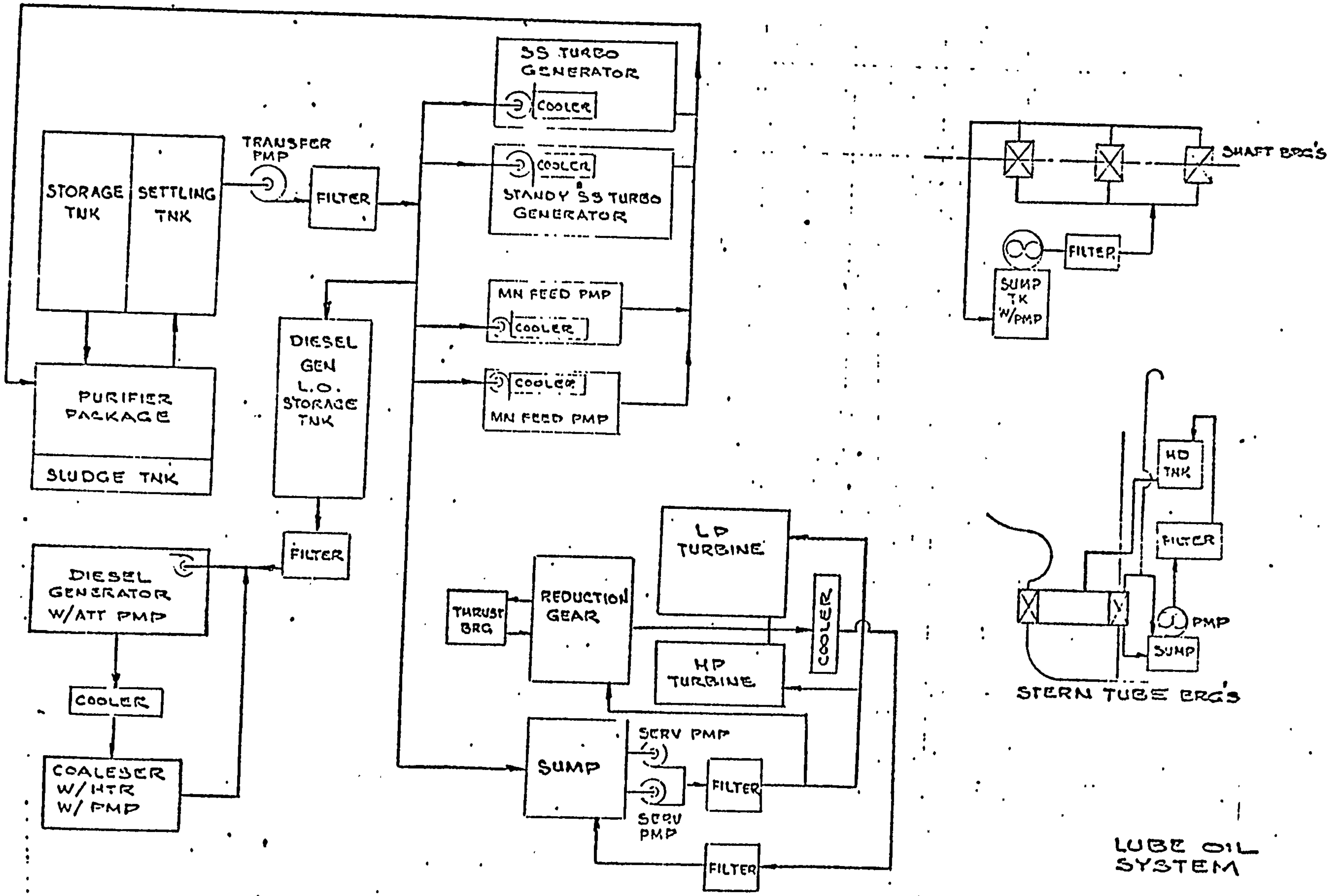

HI
OVBD
MN
OVBD
SHELL
MAIN CONDENSER
HOT WELL
L.O. COOLER
CIRC PMP
HIGH SEA CHEST
SCOOP
MAIN SYSTEM
OVBD
SS TURBO GEN CONDENSER
STAND BY SS TURBO GEN CONDENSER
OVBD
EMERGENCY DIESEL GEN JACKET WATER HT EXCHANGER
AUX COOLERS
SEA CHEST
PMP
PMP
SEA CHEST
AUXILIARY SYSTEM

FIG 3.



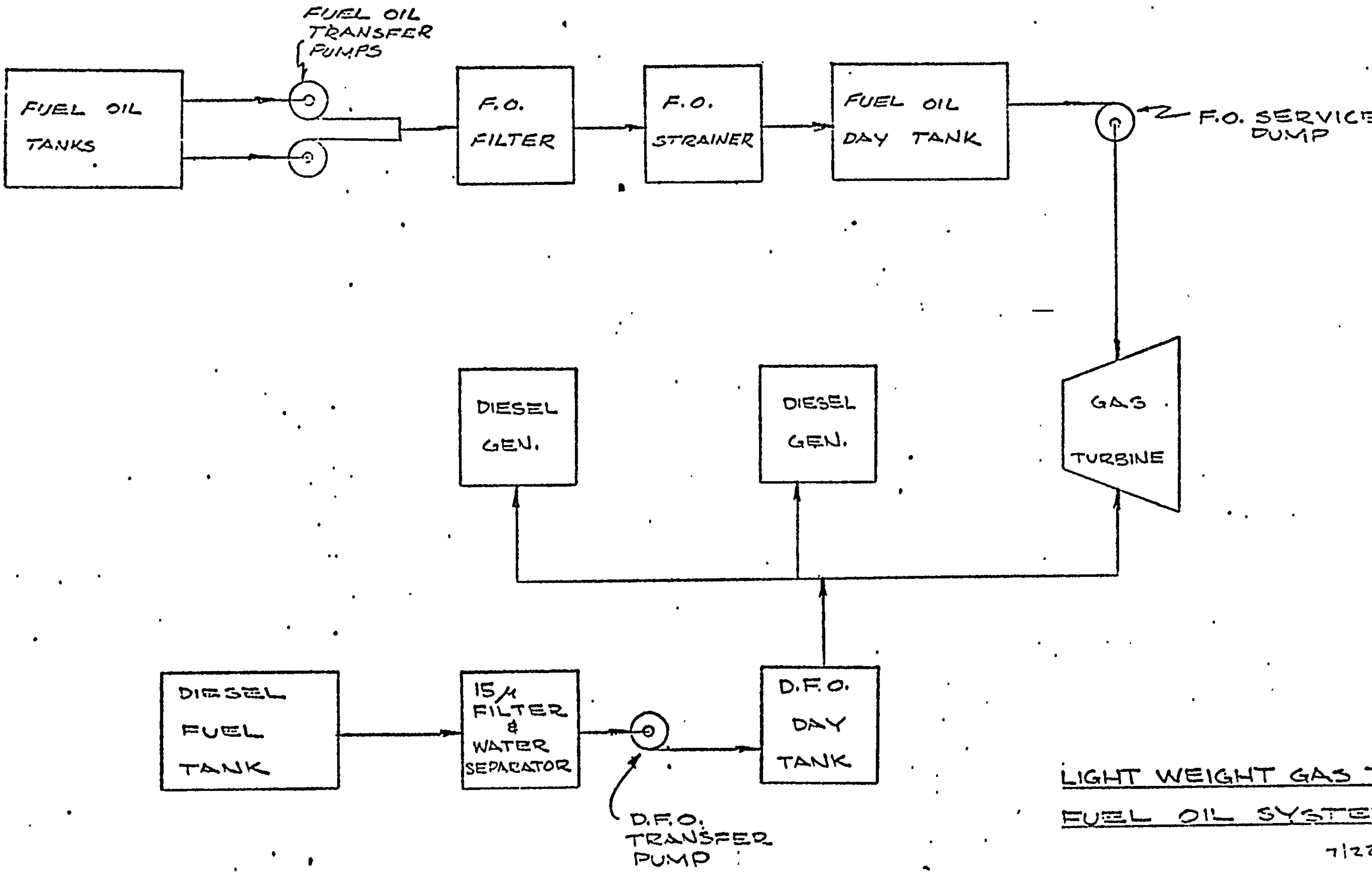
D.O. SERV SYSTEM

FIG 5



LUBE OIL SYSTEM

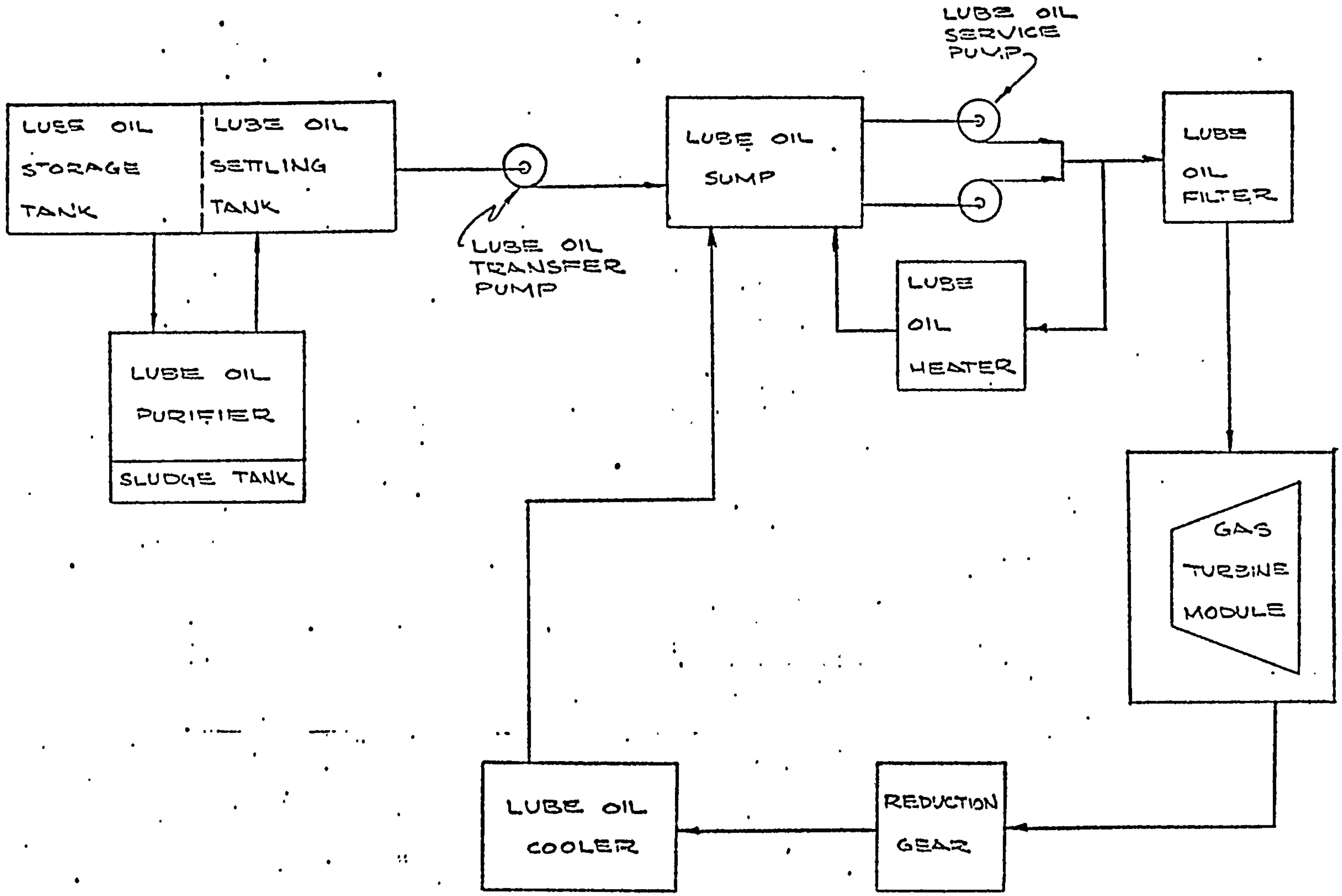
FIG 6



LIGHT WEIGHT GAS TURBINE FUEL OIL SYSTEM

7/22/74 EAL

FIG. 7



LIGHT WEIGHT GAS TURBINE

LUBE OIL SYSTEM

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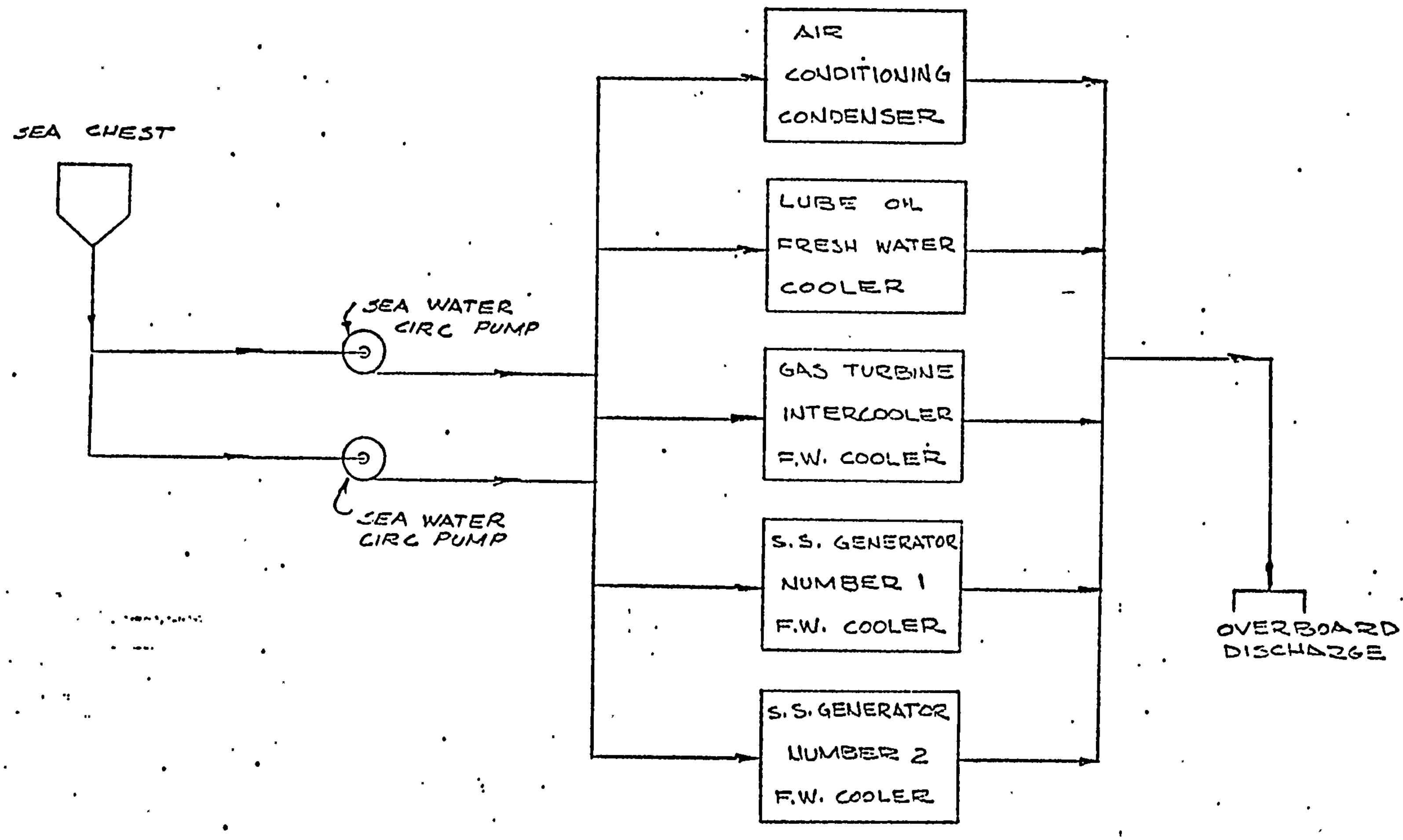
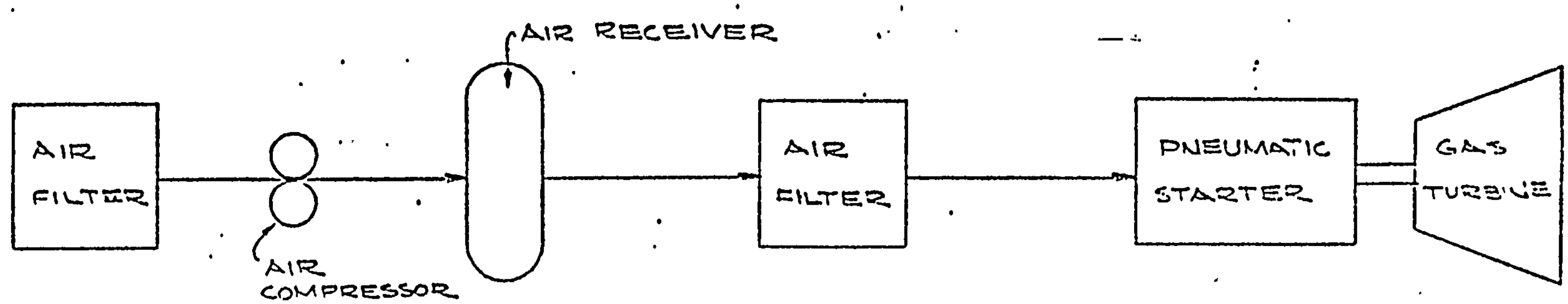
FIG. 8



LIGHT WEIGHT GAS TURBINE
SEA WATER COOLING SYSTEM

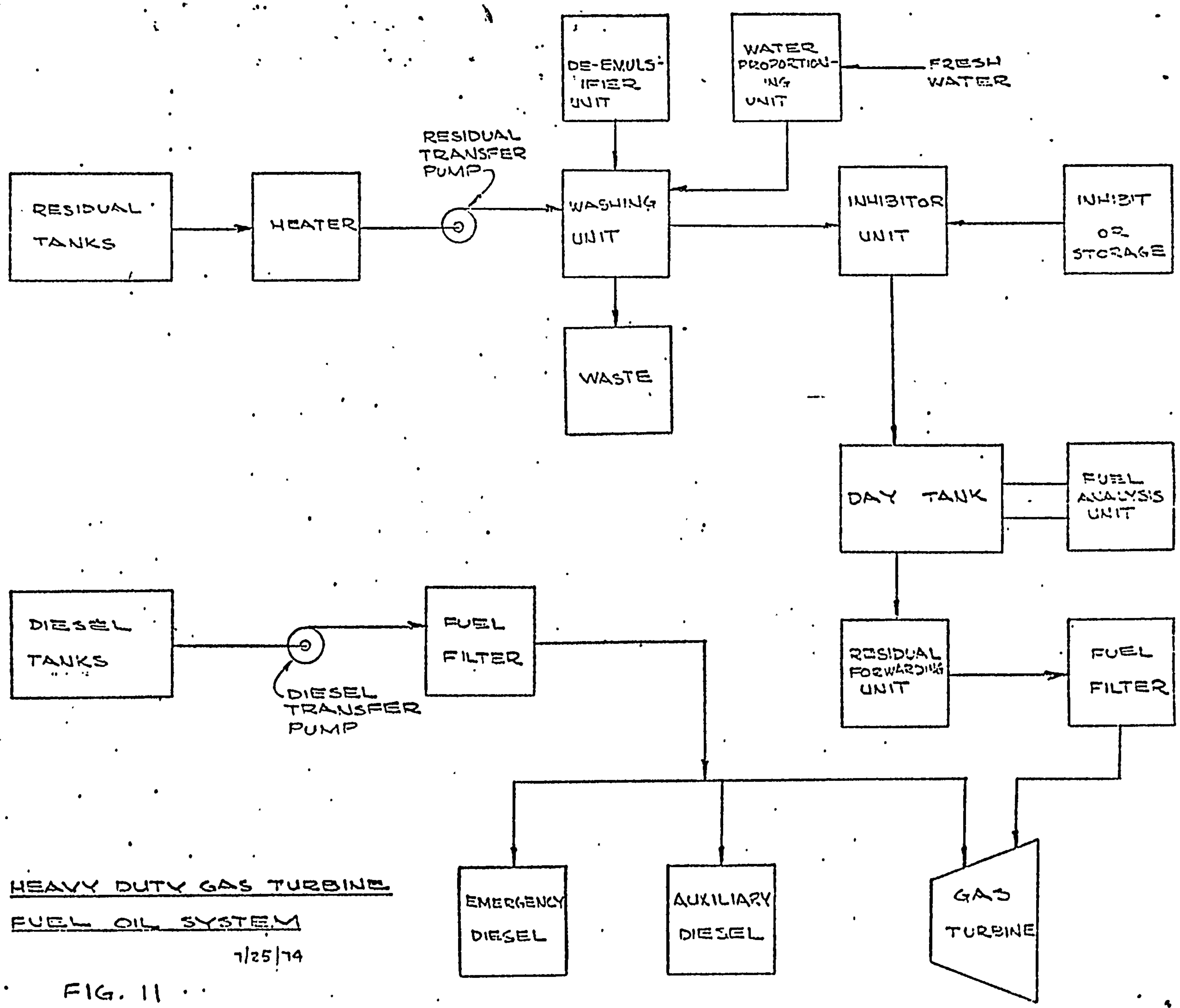
7/22/74 RAL



LIGHT WEIGHT GAS TURBINE
START AIR SYSTEM

7/22/74 RAL

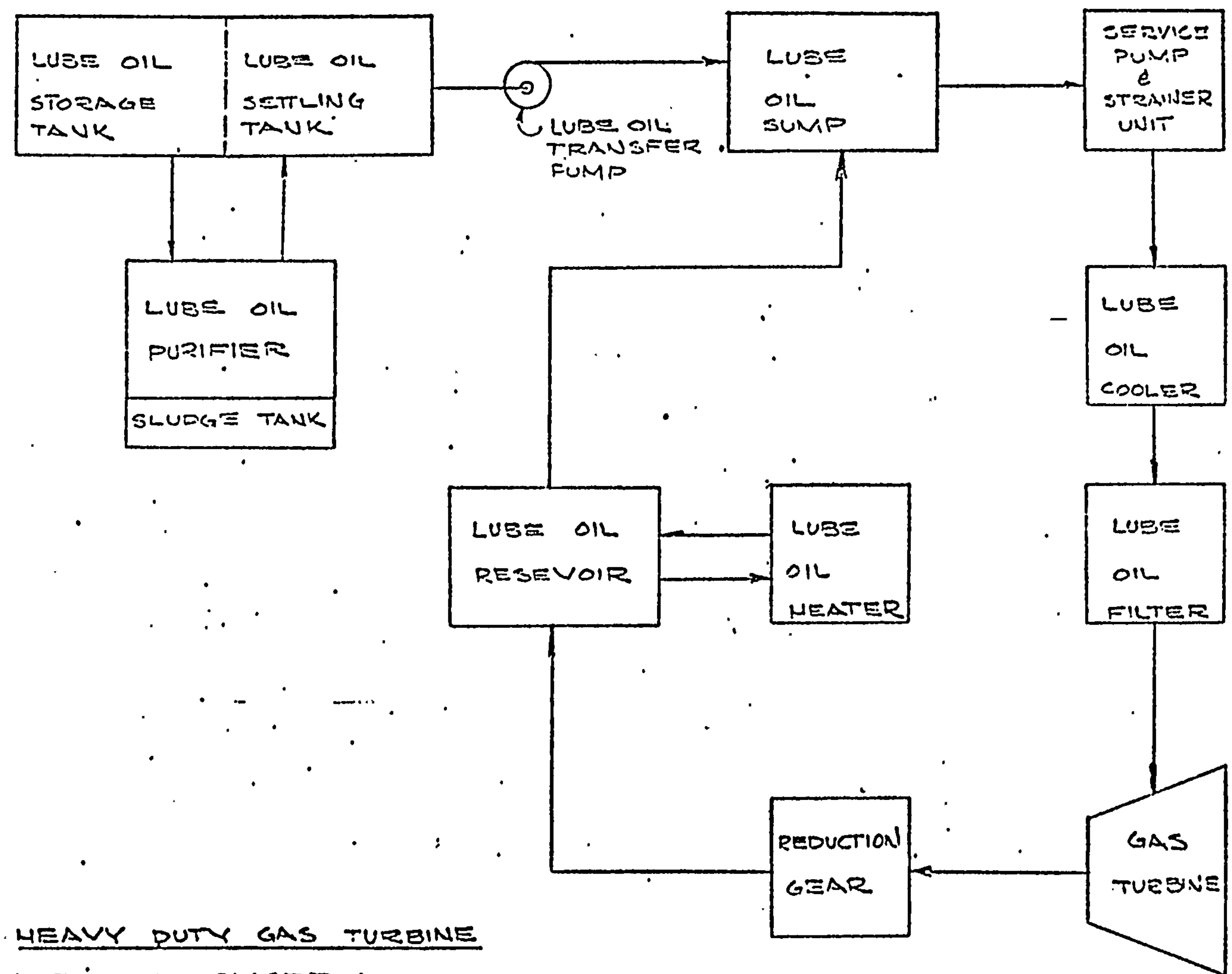
FIG. 10



HEAVY DUTY GAS TURBINE
FUEL OIL SYSTEM

7/25/74

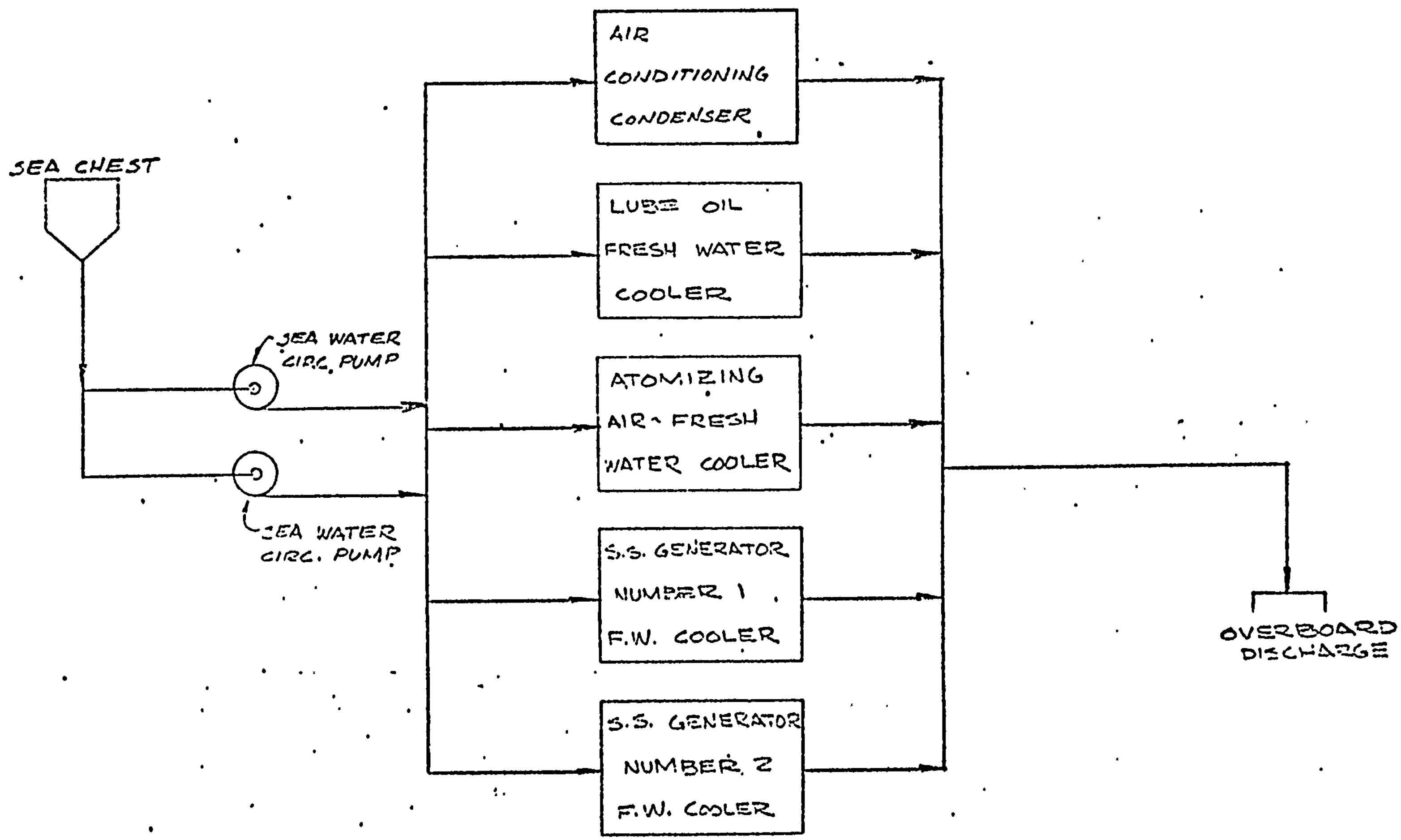
FIG. 11



HEAVY DUTY GAS TURBINE
LUBE OIL SYSTEM

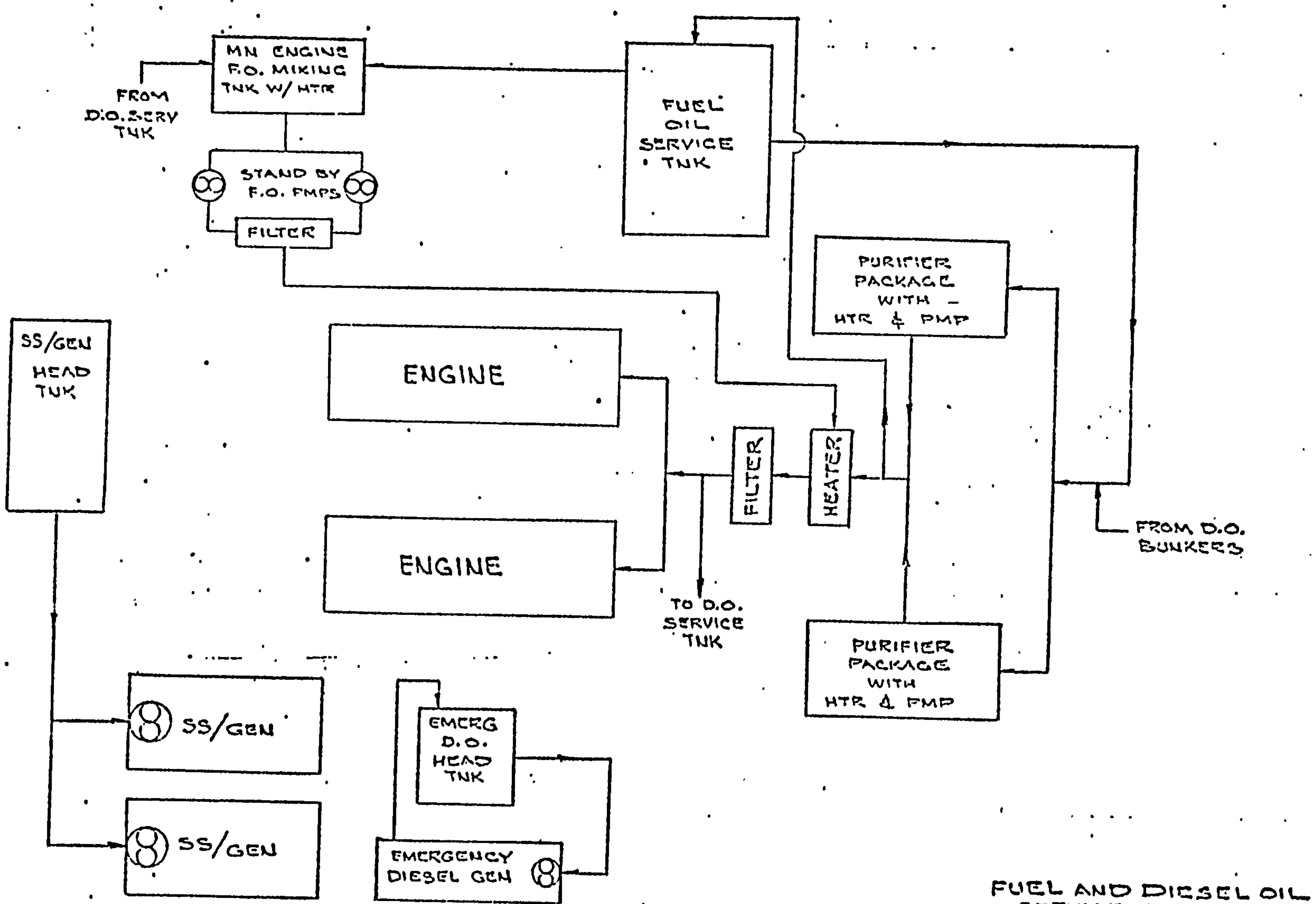
7/25/74 RAL

FIG. 12



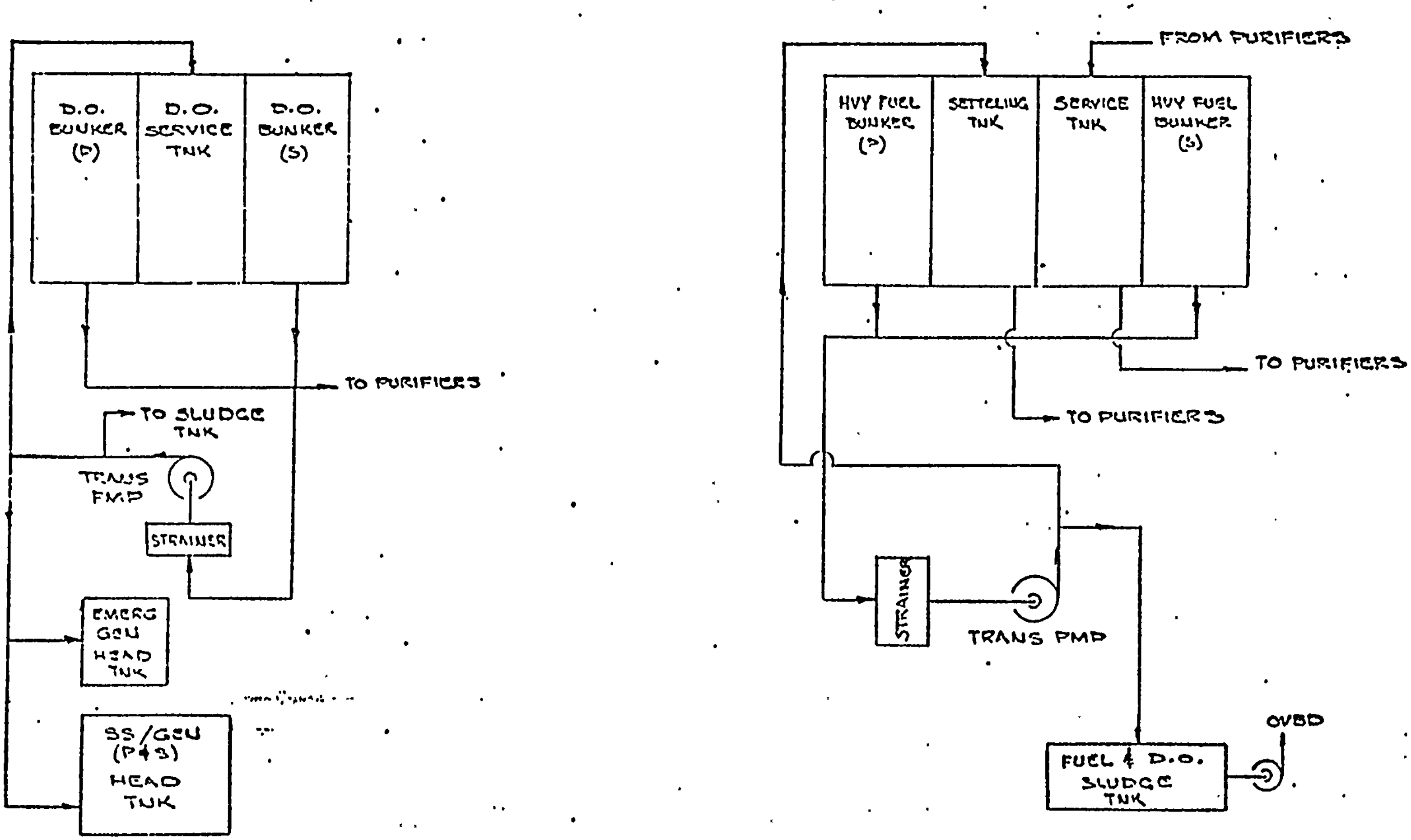
HEAVY DUTY GAS TURBINE
SEA WATER COOLING SYSTEM
7/25/76 RAL

FIG. 13



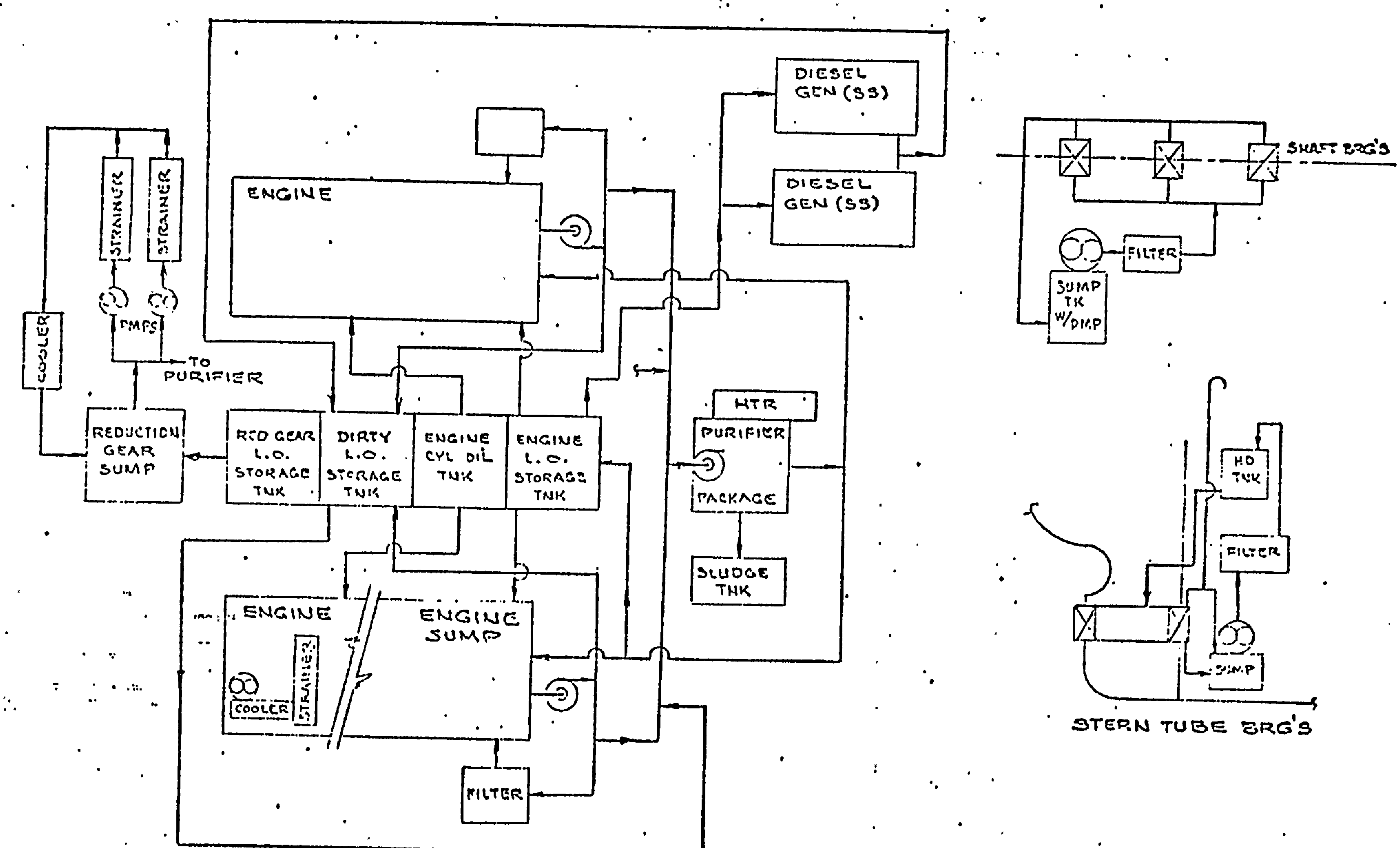
FUEL AND DIESEL OIL SERVICE SYSTEM

FIG 14



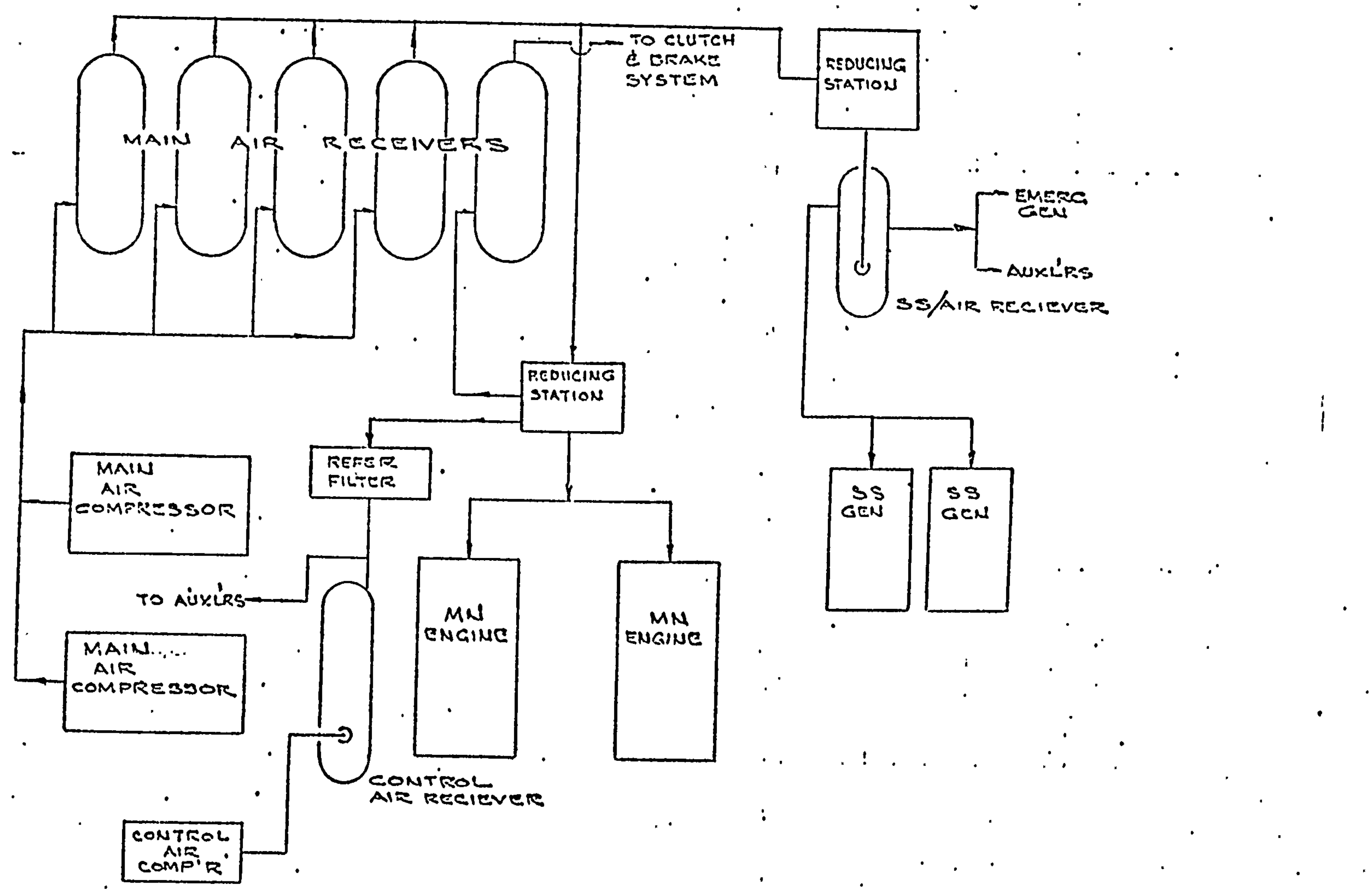
FUEL AND DIESEL OIL TRANSFER SYSTEM

FIG. 15



LUBE OIL SYSTEM

FIG. 16



STARTIN AIR AND
CONTROL AIR SYST

FIG. 17

ENGINEERING TECHNICAL NOTE #7

STANDARDIZATION OF MACHINERY LAYOUTS

FOR 150,000 DWT TANKER

H. T. CHEYNE

TN-7

D. A. Rains

ABSTRACT

A preliminary line plan for a 150,000 DWT tanker was used to develop the base line machinery arrangements for several power plant types.

INTRODUCTION

This technical note summarizes a study to investigate designing a common machinery space for a 150,000 DWT tanker so that any one of four (4) selected propulsion plants could be installed in the same sized machinery space with a minimum impact on the design of the ship structure. Also the study investigated ways to locate the machinery and auxiliaries in the same general area within the space in an effort to standardize the arrangement of machinery regardless of the type of propulsion plant selected.

1.0 Propulsion Plants

Four propulsion plants capable of developing 25,000 SHP were considered and are as follows:

(1) Steam Turbine Plant - Manufacturer - Westinghouse
Type - High Speed Cross Compound HP & LP

(2) Medium Speed Diesel - Manufacturer - Colt Pielstick
Type - 18 Cylinder "V" 3 engines required

(3) Light Weight Gas Turbine - Manufacturer - Pratt-Whitney
Type - Single FT-9

(4) Heavy Duty Gas Turbine - Manufacturer - General Elect
Type - Model MM5002R-B Frame 5 Regenerative

2.0 Design Philosophy

(1) Standardize the ship structure in the preliminary design stage to define structural assemblies and establish assembly breaks in way of the machinery space. The design of assemblies should include foundations for machinery and equipment. They should be structurally complete as far as possible to facilitate pre-outfitti of the assembly. The overall size and weight of pre-outfitted assemblies will be governed by the lifting and handling capabilitie of the shipyard.

(2) The main machinery space is to be of the minimum volume to provide. as much extra cargo space as possible.

(3) In the preliminary design layout of machinery within the space, every effort should be made to locate the machinery and components in the same general area within the machinery space regardless of the type of propulsion plant selected.

(4) Develop machinery installation packages composed of functionally related machinery and components capable of being installed in the structural assemblies in order to:

(a) Facilitate production/installation at assembly stage.
(b) Support series ship production concept.
(c) Support assembly design concept in way of machinery spaces.
(d) Permit off-ship pre-assembly of packages to effectively optimize cost benefits of production packaging by pre-outfitting the machinery spaces as much as possible in the assembly stage.

(5) During the development of the base line arrangements due consideration was given to the following:

(a) Shaft removal and accessibility
(b) Maintainability of units
(c) Lifting and withdrawal of components
(d) Location of control center

3.0 STUDY RESULTS

1. Preliminary investigation and study of the four (4) selected propulsion plants was undertaken and in the course of development of the base line arrangements it became evident that only three (3) of the four (4)power plants could be fitted into a common machinery space and meet all of the design philosophy previously outlined. The three plants are as follows: Steam Turbi Medium Speed Diesel, and Light Weight Gas Turbine.

2. The Heavy Duty Gas Turbine with its regenerator, due to its overall height, length and configuration would have required a longer overall length for the engine room and more space between deck levels and superstructure. Thus, this plant was not considered further in the evaluation.

4.0 Equipment List

A list of equipment that was used in the study can be found in Tables 1, 2, and 3. This list is preliminary at this time and quantities given are for major components. More complete information is being prepared.

Table 1	Steam Machinery List
Table 2	Medium Speed Diesel Machinery List
Table 3	Light Weight Gas Turbine Machinery List

5.0 Arrangement Drawings

Machinery arrangement drawings have been prepared for this study and are as follows:

Plan No. 1	Steam Turbine Arrangement
Plan No. 2	Medium Speed Diesel Arrangement
Plan No. 3	Light Weight Gas Turbine Arrangement

6.0 Conclusions

Three (3) base line machinery arrangements were developed and standardization of the machinery space and machinery layout was achieved in the following areas:

1. Established common overall length of machinery space for all three arrangements.
2. Selected common heights for deck and machinery flat levels within the machinery space capable of servicing any of the three (3) selected plants.
3. Located the main fuel tanks within the machinery space common for all three arrangements.
4. Located main access hatches and ladders common for all three arrangements.
5. Located main grating levels. common for all three machinery arrangements.
6. The main reducticn gears were located in the same relative position for all three machinery arrangements.
7. Selected main propulsion shaft height above base line common for all three propulsion plants.
8. Selected propeller shaft overall length common for all three arrangements
9. Located line shaft bearing positions common for all three arrangements
10. Machinery identified as installation packages was located in all three machinery arrangements in the same relative position and are as follows:

a. Fuel oil equipment.
b. Sub-oil equipment
c. Ship service generators
d. Distilling plant and pump
e. Starting air system
f. Local operating station
g. Boiler feed tank and pumps
h. Sub-oil storage tanks.
j. S.W. cooling pumps
k. Main engine fuel oil day tanks
l. Ships service generator: fuel oil day tanks
m. Sewage plant
n. Fire pumps
o. Bilge pumps

7.0 Summary

This study demonstrates the feasibility of standardization within the machinery space, but it would be necessary to do a more detailed study of outfitting the complete machinery space as outlined in the three (3) basic machinery arrangements. This study together with the machinery arrangements should serve as an excellent basis for such an effort. In present day ship constructi it is necessary to consider the work functions of the various engineering and design departments involved and the inter-relations between them and establish effective liaison during the early phase of ship design, particularly in relationship to machinery space design. The development of new techniques in ship production such as fabricating assemblies, pre-outfitting machinery in the assembly stage, installing piping, valves fitting, wireways, vent duces, etc. within assemblies only stress the need for effective pre-planning, and close cooperation by engineering design departments and production. The implementation of maximum off-ship pre-assembly and ship assembly outfitting in the main machinery space area prior to launching and the consequent reduction of time, labor and cost expenditures during ship assembly should result in an overall cost saving in ship production.

TABLE 1

STEAM PROPULSION PLANT AND AUXILIARY MACHINERY LIST

DESCRIPTION		
1.	HP Turbine	1
2.	LP Turbine	1
3.	Reduction Gear	1
4.	Thrust Bearing	1
5.	Line Shaft Bearing	2
6.	Shafting	1 Ship Set
7.	Propeller (Fixed Pitch)	1
8.	Main Condenser	1
9.	Main Circ. Pump	1
10.	Vacuum Equipment	1
11.	Atmospheric Drain Inspection Tank & Pump	1
12.	Contaminated Drains Tank	1
13.	S.W. Service Pump	1
14.	1st Stage Feed Heater Gland Exhaust Condenser and Drain Cooler	1
15.	Third and Fourth Stage Feed Heater	1
16.	Lube Oil Cooler	1
17.	Lube Oil Pumps	1
18.	Lube Oil Purifier	1
19.	Fire Pumps	2
20.	Bilge Pumps	2
21.	Ships Air Compressor	2
22.	Control Air Compressor	1
23.	Air Receivers	2
24.	Control Air Receiver	1
25.	Main Boilers	2
26.	Main Feed Pumps	2
27.	Boiler Test Stand	1
28.	Distilling Plant & Pump	1
29.	Distilling Plant Overboard Pump (Brine)	1
30.	Ships Service Generator (Steam)	2
31.	Local Operating Station	1
32.	Sewage Plant	

TABLE 2

MEDIUM SPEED DIESEL PROPULSION PLANT &
AUXILIARY MACHINERY LIST

	DESCRIPTION	QTY.
1.	Main Diesel Engines	3
2.	Reduction Gear	1
3.	Thrust Bearing	1
4.	Line Shaft Bearings	2
5.	Shafting	1 Ship Set
6.	Propeller (Fixed Pitch)	1
7.	Ships Service Air Compressors	3
8.	Ships Service Air Receivers	5
9.	Main Engine S.W.Circ. Pumps	3
10.	Standby S.W. Circ. Pumps	3
11.	ME Jacket Water Coolers	3
12.	ME CW Expansion Tanks	3
13.	ME Lube Oil Coolers	3
14.	Main Reduction Gear Lube Oil Cooler	1
15.	Main Reduction Gear Standby Lube Oil Cooler	1
16.	Lube Oil Purifiers	3
17.	Lube Oil Pump (Engine Driven)	3
18.	Standby Lube Oil Pumps	3
19.	ME Jacket Water Pumps (Engine Driven)	3
20.	Standby Jacket Water Pumps	3
21.	Injector Cooling Pump	3
22.	Standby Injector Cooling Pumps	3
23.	Fuel Oil Boost Pumps	2
24.	Fuel Oil Duplex Strainer	1
25.	Fuel Oil Filter	1
26.	Fuel Oil Transfer Pumps	2
27.	Fuel Oil Purifiers	2
28.	Heavy Fuel Oil Pre-Heaters	2
29.	Final Fuel Oil Heaters	2
30.	Fire Pumps	2
31.	Bilge Pumps	2
32.	Shaft Bearing Lube Oil Package	1

TABLE 2 (Continued)

33.	Stern Tube Lube Oil Package	1
34.	Ships Service Diesel Generators	2
35.	Distilling Plant & Pump	1
36.	Distilling Plant Brine Overboard Pump	1
37.	Local Operating Station	1

TABLE NO. 3
LIGHT WEIGHT GAS TURBINE PROPULSION PLANT & AUXILIARY MACHINERY LIST

	DESCRIPTION	QTY.
1.	Main Engine FT9	1
2.	Reduction Gear (Reversing)	1
3.	Thrust Bearing	1
4.	Line Shaft Bearings	2
5.	Propeller (Fixed Pitch)	1
6.	Ships Service Air Compressor	2
7.	Ship Service Air Receivers	5
8.	Control Air Compressor	2
9.	Fuel Oil Service Pump	1
10.	Fuel Oil Transfer Pump	2
11.	Fuel Oil Filter	1
12.	Fuel Oil Duplex Strainer	1
13.	Fuel Oil Heater	1
14.	Lube Oil Service Pumps	2
15.	Lube Oil Purifier	1
16.	Lube Oil Cooler (Mn. Red. Gear)	1
17.	Sludge Pump	1
18.	Lube Oil Duplex Strainer	1
19.	S.W. Cooling Pumps	2
20.	Fire Pumps	2
21.	Bilge Pumps	2
22.	Sewage Plant	1
23.	Distilling Plant and Pump	1
24.	Distilling Plant Brine Overboard Pump	1
25.	Boiler Feed Pump	1
26.	Ship Service Diesel Gen.	2

MARINE ENGINEERING TECHNICAL NOTE #10

OPTIMUM GAS TURBINE POWERED SHIP PROPULSION & AUXILIARY POWER GENERATION

DR. DEAN A. RAINS

2 APRIL 1974

TN-10

J. C. COUCH
CHIEF MARINE ENGINEER

APPENDIX D

ECONOMIC POWER PLANT TRADEOFFS

OPTIMUM GAS TURBINE POWERED SHIP PROPULSION
& AUXILIARY POWER GENERATION

ABSTRACT

One possible method of improving overall gas turbine plant fuel consumption is to utilize-the main engines to drive the ship service generators in part or totally.

This method has been investigated and shows promise, especially when the ship service generator drive is inferior in performance to the main engines.

SUMMARY

The analytical results presented herein indicate the bounds of performance where driving the ship service generators in part or totally by the main engines can save up to 13% in fuel consumption if the SFC are tine same and up to 30% savings if SFC for the ship service generator is 50% higher than the main engines. Loading of the main engines and thus improving thieir SFC, plus taking advantage of the fact that larger engines have better SFC's accounts for the improved performance. Several plant configurations to achieve these results are proposed.

ANALYSIS

The nomenclature used in the analysis of the optimum participation of the main engines and ship service gas turbines in driving the ship service generators is listed below:

W_F	Total Fuel Load	(LB)
P_E	Electrical Power	(HP)
P_P	Propulsion Power	(HP)
γ	Fraction of Electrical Power Developed By Main Engines	(-)
Δt	Time Period	(hr)
x	Exponent	
SFC_E	Electrical Plant SFC	(lb/hp.hr)
SFC_P	Propulsion Plant SFC	(lb/hp.hr)
k	SFC Coefficient	(lb/hp.h
i	= 1,2,3,1 Period Identifiers	
*	Maximum Superscript	
λ, A,Y,Z	Constants as Defined	

Also define:

$$SFC_E = \frac{k_E}{\left(P_E/P_E^*\right)^x} \qquad SFC_P = \frac{k_P}{\left(P_P/P_P^*\right)^x}$$

Where for most gas turbines x = .15-.25 and k_E and k_P are between .40 and .70 lb/hp.hr

The total fuel consumption for a ship at

$$W_F = \sum_{i=1}^{n} \Delta t_i \, SFC_E \left(P_{Ei} - \gamma P_{Ei}\right) + \sum_{i=1}^{n} \Delta t_i \, SFC_P \left(P_{Pi} + \gamma P_{Ei}\right)$$

$$= \sum_{i=1}^{n} \Delta t_i \, P_E^{*x} k_E \left(P_{Ei} - \gamma P_{Ei}\right)^{1-x} + \sum_{i=1}^{n} \Delta t_i \, P_P^{*x} k_P \left(P_{Pi} + \gamma P_{Ei}\right)^{1-x}$$

Where γ is the fraction of the electrical power generated by the main engines.

The ratio of interest is $\frac{W_F}{W_{F\,\gamma=0}}$ to determine the payoff:

$$\frac{W_F}{W_{F_{\gamma=0}}} = \frac{\sum_{i=1}^{n} \Delta t_i \, P_E^{*x} k_E \left(P_{Ei} - \gamma P_{Ei}\right)^{1-x} + \sum_{i=1}^{n} \Delta t_i \, P_P^{*x} k_P \left(P_{Pi} + \gamma P_{Ei}\right)^{1-x}}{\sum_{i=1}^{n} \Delta t_i \, P_E^{*x} k_E \left(P_{Ei}\right)^{1-x} + \sum_{i=1}^{n} \Delta t_i \, P_P^{*x} k_P \left(P_{Pi}\right)^{1-x}}$$

As a limiting case, which in most cases is the most beneficial, take $\gamma = 1.0$ in the numerator

$$\frac{W_{F\gamma=1}}{W_{F\gamma=0}} = \frac{\sum_{i=1}^{n} \Delta t_i P_P^{*x} k_p (P_{Pi} + P_{Ei})^{1-x}}{\sum_{i=1}^{n} \Delta t_i P_E^{*x} k_E (P_{Ei})^{1-x} + \sum_{i=1}^{n} \Delta t_i P_P^{*x} k_p (P_{Pi})^{1-x}}$$

Defining:

$$\frac{k_E}{k_p} = A \qquad \frac{P_{Ei}}{P_{Pi}} = Z_i \qquad \frac{\Delta t_i}{\Delta t^*} = \lambda_i \qquad \frac{P_E^*}{P_P^*} = Z^* \qquad \frac{P_{Pi}}{P_P^*}$$

$$\frac{W_{F\gamma=1}}{W_{F\gamma=0}} = \frac{\sum_{i=1}^{n} \lambda_i Y_i^{1-x} (1+Z_i)^{1-x}}{\sum_{i=1}^{n} \lambda_i A Z^{*x} Y_i^{1-x} Z_i^{1-x} + \sum_{i=1}^{n} \lambda_i Y_i^{1-x}}$$

$$\frac{W_{F\gamma=1}}{W_{F\gamma=0}} = \frac{\sum_{i=1}^{n} \lambda_i Y_i^{1-x} (1+Z_i)^{1-x}}{\sum_{i=1}^{n} \lambda_i Y_i^{1-x} \left(1 + A Z^{*x} Z_i^{1-x}\right)}$$

$\gamma = 1$ Corresponds to the case where all of the electrical power comes from the main engines.

If $Z_i = Z^*$ is a constant for the various time periods; that is the ratio of electrical to propulsion power is a constant then:

$$\frac{W_{F\gamma=1}}{W_{F\gamma=0}} = \frac{(1 + Z^*)^{1-x}}{(1 + A Z^*)}$$

Although this simplification may not be totally valid, electrical power requirements do tend to follow propulsion needs to some degree. The more general equations can be used for specific evaluation of the concept, but this simple relation should provide valuable insight.

A plot of this ratio is shown on Figure 1 for the following values of the parameters

$$\chi = 0.20$$

$$Z^* = 0.1 \longrightarrow 1.0 \qquad \text{Where } Z^* = P_E/P_P$$

$$A = 1.0,\ 1.25,\ 1.50 \qquad \text{Where } A = k_E/k_P$$

A table of values is also presented below:

$$\frac{W_{F\,\delta=1}}{W_{F\,\gamma=0}} = \frac{\text{Fuel Needed - Combined Source}}{\text{Fuel Needed - Separate Source}}$$

k_E/k_P = / P_E^*/P_P^*	1.0	1.25	1.5
.1	0.98	0.960	0.940
.2	0.965	0.925	0.890
.3	0.950	0.895	0.850
.4	0.935	0.870	0.815
.5	0.920	0.850	0.790
.6	0.910	0.830	0.765
.7	0.900	0.815	0.745
.8	0.890	0.800	0.728
.9	0.880	0.785	0.711
1.0	0.870	0.774	0.695

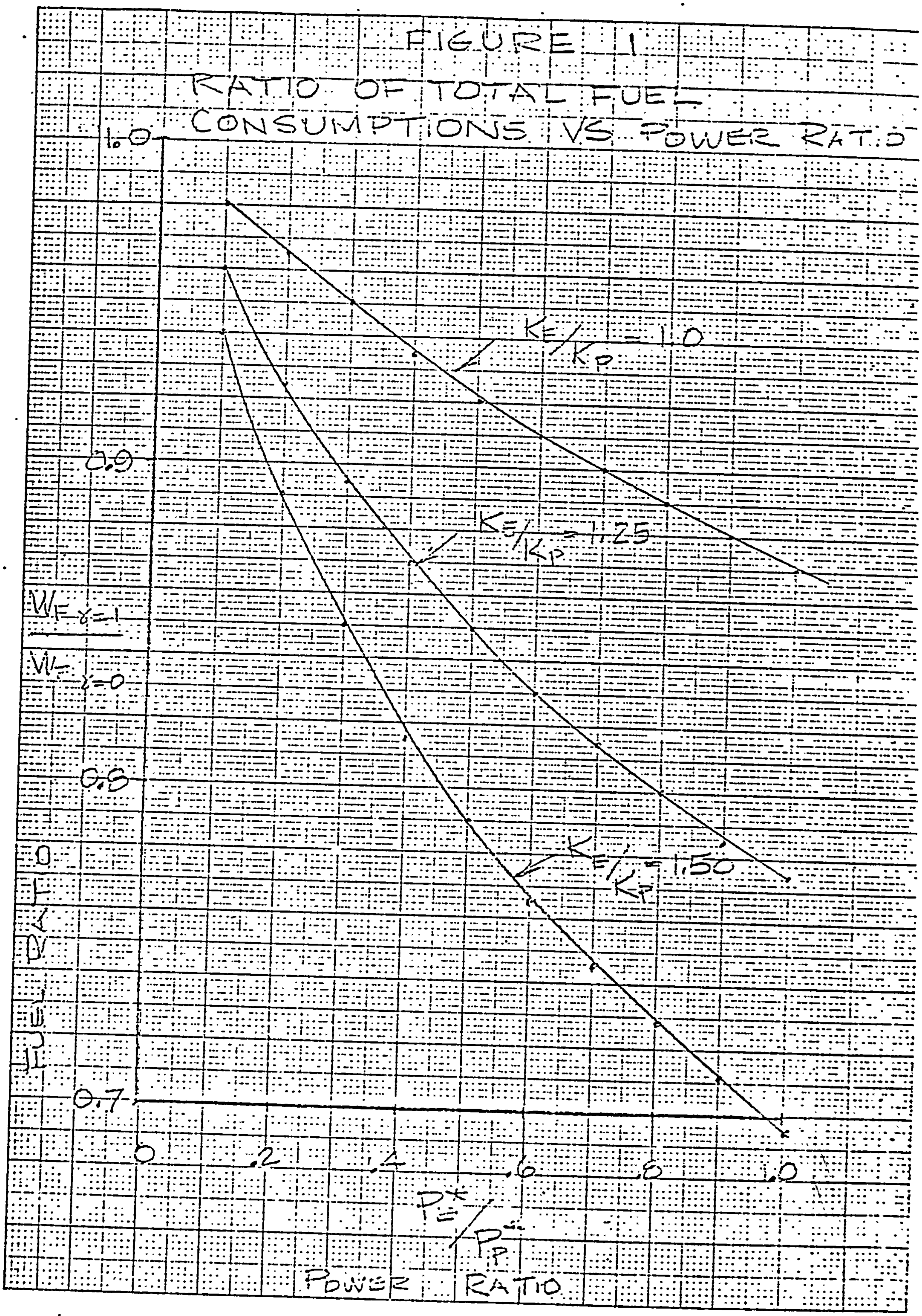


FIGURE 1
RATIO OF TOTAL FUEL CONSUMPTIONS VS POWER RATIO
1.0
0.9
0.8
0.7
$W_{F\,\gamma=1} / W_{F\,\gamma=0}$
FUEL RATIO
$K_E/K_P = 1.0$
$K_E/K_P = 1.25$
$K_E/K_P = 1.50$
0
.2
.4
.6
.8
1.0
P_E^* / P_P^*
POWER RATIO

As an example of the use of these curves or table consider the case when the full power SFC for the SSG is 1.25 times the main engine value (k_E = 0.50 lb/hp.hr and k_P = 0.40 lb/hp.hr) and electric power is 3000 hp and the propulsion power is 9000 hp then the fuel weight ratio is 0.87 or a 13% saving by combining power sources.

CONFIGURATIONS

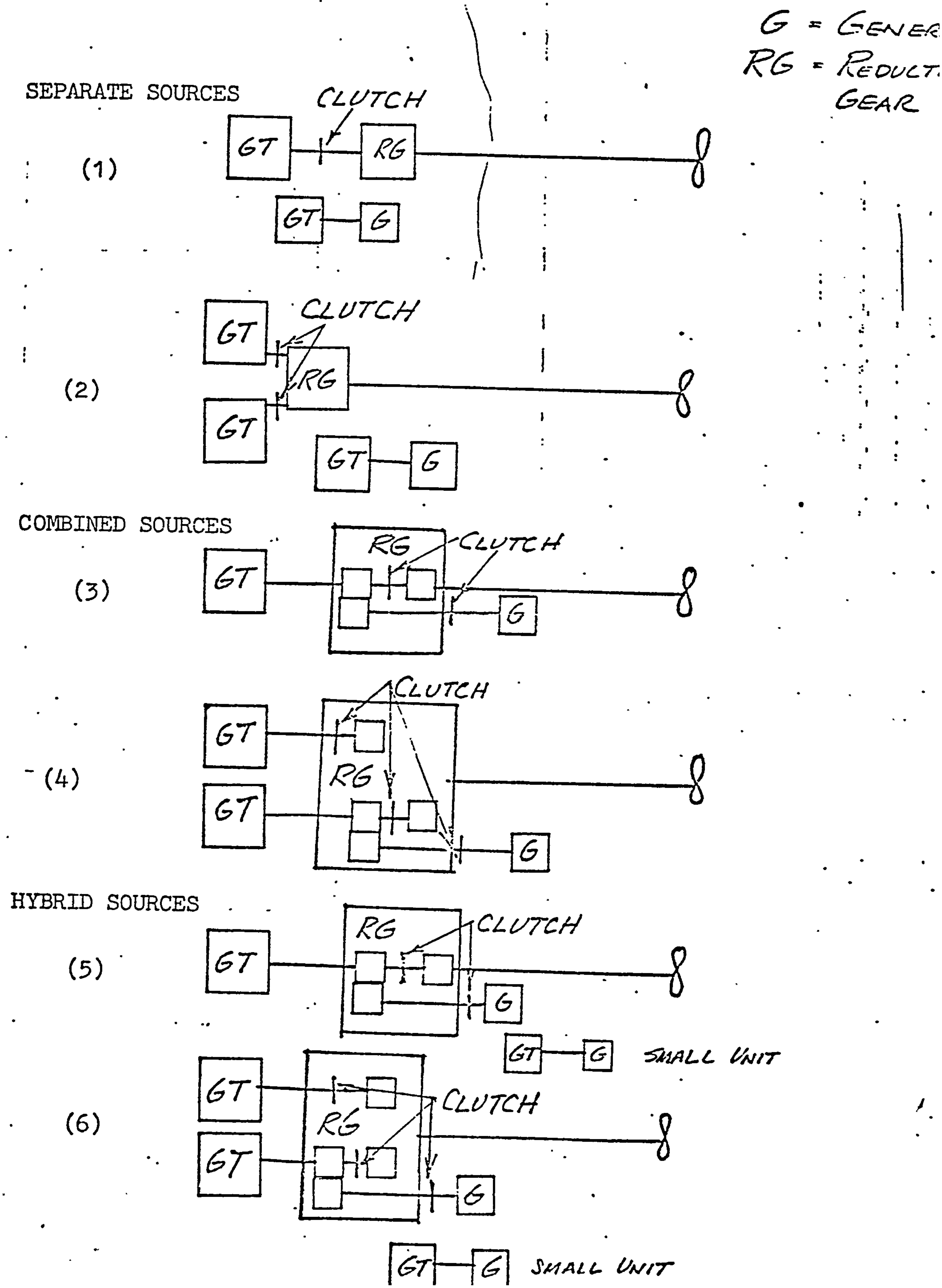
Figure 2 suggests some plant configurations to take advantage of this fuel consumption advantage. The conventional separate source configurations are (1) and (2). The combined source configurations are (3) and (4). If it proves important to have separate shore or emergency power, or some mix of separate and combined power sources (5) and (6) are hybrid configurations combining the capabilities of both approaches. Note in all of the combined source configurations (3) thru (6) that separate clutches permit driving the generators with the main engines without driving the propeller shaft. A weight and an airborne and structure borne noise reduction should also be a result of combining the plants. Machinery arrangements shoul be more straightforward as well.

CONCLUSIONS

A preliminary analysis indicates that combining the power sources for electrical and propulsion power aboard ship can lead to a significant reduction of plant fuel consumption. It is recommended that further study of these or similar concepts be carried out for specific applications.

FIGURE 2

ALTERNATE PLANT CONFIGURATIONS



MARINE ENGINEERING TECHNICAL NOTE #7A

A PROPULSION PLANT COMPARISON FOR 120,000 DWT TANKER

B. T. Jeavons, D. A. Rains & H. T. Cheyne

1 APRIL 1974

TN-7 A

J. C. COUCH
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A PROPULSION PLANT COMPARISON FOR 120,000 DWT TANKER

ABSTRACT

A preliminary study was conducted to assess the relative merits of five propulsion plants for a 120,000 dwt tanker requiring 25,000 HP to propel it at approximately 16K. The five plants studied were medium speed diesel, steam turbine, heavy duty gas turbine (mechanical drive and electric drive), and aircraft derivative gas turbine. The heavy duty gas turbine (mechanical drive) and the aircraft derivative gas turbine utilizes a CRP propeller. The diesel uses a reversing engine for maneuvering. Preliminary economic analysis and engine room layouts were principal parts of the study.

SUMMARY

The economic analysis compared effective annual operating costs for the five plants. Costs included investment capital, fuel, oil, crew, maintenance and repair and insurance cost. The study showed that the medium speed diesel and aircraft gas turbine are on a par with each other costwise, with the steam and industrial gas turbine significantly more expensive to own and operate. The layouts show that there is sufficient space for any of the five power plants within the desired hull. The aircraft gas turbine is the most convenient to locate and the heavy duty gas turbine second. A noise isolating foundation for the diesel engine was included in the design to reduce the shipboard vibration. It consists of a raft-type bedplate mounted on standard Navy mounts.

ANALYSIS

The following assumptions were made in the economic trade-off analysis:

Dollars = 1975 (1.08 Annual Escalation)

Operating time = 7,000 Hrs./Yr.

Annual Cost Factor = 0.125
(Annual Cost = 0.125 X First Cost)

HP = 25,000 HP

Fuel Cost - Diesel Oil = \$11.00/BBL
Bunker C = \$10.00/BBL

Lube Oil - \$2.50/Gallon

ANALYSIS (Continued)

Crew Costs	$100,000/Yr All crew sizes the same except steam - Add 5 men for steam plant.

Fuel treatment considered for HD Gas Turbine

No auxiliary costs included (See Ref. 1 for Auxiliary Cost Study)

RESULTS

The fuel consumption rates are shown in Table I. The values are all based on the fuels noted. The aircraft gas turbine performance is based on an uprated LM-2500*. Table II shows the resulting fuel costs. Table III indicates the lube oil costs. Note the high dollar value of the diesel lube oil compared to the other power plants. This is due to the high consumption rate and much increased cost of lube oil. Table IV gives an acquisition and installation cost breakdown for each of the five plants. Note that the principal difference between the diesel and aircraft gas turbine is the cost of the CRP. A thrust reverser of a twin tudder type or some other similar approach to replace the CRP may bring these two systems into line. Table V shows the first cost of the fuel treatment plant and tabulates the annual operating cost of the plant. Table VI summarizes the annual cost comparison. Note that the diesel and aircraft gas turbines are nearly equal while the heavy duty engine and steam turbine are about 15% higher in cost.

DESIGN LAYOUTS

Design layouts were prepared for three of the propulsion plants. They are shown in Figures 1, 2, 3, and 4 120,000 DWT-1, 120,000 DWT-2, 120,000 DWT-3, 120,000 DWT-4. Note the large amount of space available in the engine rooms, especially the singl aircraft gas turbine plant. There is sufficient space for ship service generators and the other necessary auxiliaries.

The only medium speed diesel available in the U.S. market was DeLaval Enterprise Model DMRV-20-4. It was larger than most of the other 12,500 hp diesels. It is operating at the upper limit of its growth capability. If the tanker is built without U.S. subsidy, other diesels could be considered.

Reference: 1) TN-8; D.A. Rains "Steam Generation System Evaluation for a 120,000 Ton Tanker"

*Currently under G.E. development.

TABLE I

POWER PLANT PERFORMANCE

MAX. POWER SFC - LBS/HP-HR

	DIESEL	BUNKER C
MEDIUM SPEED DIESEL	.366	-
STEAM TURBINE	-	.480
HEAVY DUTY GAS TURBINE (MECHANICAL DRIVE)	.436	.453
HEAVY DUTY GAS TURBINE (ELECTRIC DRIVE)	.436	.453
AIRCRAFT DERIVATIVE GAS TURBINE	.380	-

TABLE II

FUEL COSTS

BASED ON 7000 HRS/YR AT FULL POWER
NOT INCLUDING PORT/DOCKSIDE PROPULSION

FUEL COST –	DIESEL –	\$11/BBL
	BUNKER C –	\$10/BBL (WITHOUT FUEL TREATMENT) \$10.80/BBL (WITH FUEL TREATMENT)
SPECIFIC GRAVITY –	DIESEL –	0.85
	BUNKER C –	0.97

	($ X 10^{-3}) DIESEL FUEL	($ X 10^{-3}) BUNKER C
MEDIUM SPEED DIESEL	2,370	–
STEAM TURBINE	–	2,520
HEAVY DUTY GAS TURBINE (MECHANICAL DRIVE)	2,820	2,260 (2) 2,517 (1)
HEAVY DUTY GAS TURBINE (ELECTRIC DRIVE)	2,820	2,260 (2) 2,517 (1)
AIRCRAFT DERIVATIVE GAS TURBINE	2,460	–

(1) WITH FUEL TREATMENT
(2) WITHOUT FUEL TREATMENT

TABLE III

LUBE OIL COST

DIESEL MEDIUM SPEED	–	$145 X 10^3$ (CRANKCASE)
STEAM TURBINE	–	$2.90 X 10^3$ (TURBINES & GEARS)
HEAVY DUTY GAS TURBINE	–	$2.90 X 10^3$ (TURBINES & GEARS)
AIRCRAFT DERIVATIVE GAS TURBINE	–	$8.80 X 10^3$ (TURBINES & GEARS)

TABLE IV

DETAILED COST ESTIMATES FOR POWER PLANTS

	($ X 10^{-3}) MEDIUM SPEED DIESEL (REVERSING)	($ X 10^{-3}) STEAM	($ X 10^{-3}) HEAVY DUTY GAS TURBINE (MECH. DRIVE)	($ X 10^{-3}) HEAVY DUTY GAS TURBINE (ELECT. DRIVE)	($ X 10^{-3}) AIRCRAFT DERIVA GAS TURBINE
ENGINE & DRIVE GEAR(1)	2,800	1,500	3,800	4,650	2,810
BOILER	–	1,000	–	–	–
PROPELLER	100**	100	450*	100**	450*
CONTROLS	292	350	450	450	450
MISC. (SHAFTING, BEARINGS, AUX. ETC.)	573	2,200	720	720	720
TOTAL	3,765	5,150	5,320	5,920	4,430
INSTALLATION, OVERHEAD G&A, FEE = 1.35 X (TOTAL)	5,090	7,000	7,180	7,990	5,980

*CRP PROPELLER
**FIXED PITCH PROPELLER

NO SPARES

(1) INCLUDES REDUCTION GEAR OR ELECTRIC MOTOR AS APPLICABLE

TABLE V

FUEL TREATMENT COST

ASSUME BUNKER C - 70 PPM VANADIUM

- FIRST COST FUEL TREATMENT PLANT $500,000

INSTALLATION, OVERHEAD, FEE = FIRST COST X 1.35

= $675,000 FIRST COST INSTALLED

ANNUAL OPERATIONAL COSTS (BASED ON 7000 HOURS OF OPERATION)

EQUIPMENT	84,375	
DEMULSIFIER	8,346	
MgO	10,412	
DISTILLED H_2O	9,450	
FUEL FOR POWER (ELECTRICAL & MECHANICAL)	49,285	
GENERATOR (DIESEL)	5,400	($42,700 First Cost)
MAINTENANCE	7,000	
VOLUME FOR EQUIPMENT & FLUID	12,600	($15/$Ft^3$)
	186,838	

$$\frac{\$186{,}838/\text{Year}}{233{,}000\ \text{Bl/Yr}} = \$.80/\text{Bl}$$

TABLE VI

SUMMARY COST ANALYSIS

($ X 10^{-3})

IRST COST (1975)	MED. SPD DIESEL FIXED PITCH PROPELLER	STEAM FIXED PITCH PROPELLER	HEAVY DUTY GAS TURBINE CRP PROPELLER	AIRCRAFT DERIVATIVE CRP PROPELLER	HEAVY DUTY GAS TURBINE DRIVE FP PROPELLER
	5,090	7,000	7,180	5,980	7,990
IRST COST 0.125	635	875	900	750	998
REW (Δ OVER BASELINE)	–	500	–	–	–
JEL COST	2,370	2,570	2,820	2,460	2,820 Diesel 2,517 Bunker(
AINTENANCE & REPAIR COST	110	44	101	126	101
JBE OIL COST	145	3	3	9	3
TOTAL	3,260	3,992	3,824	3,345	3,922 Diesel (3,619 Bunker C

(1) With Fuel Treatment
Does Not include Cost
of Fuel Treatment Plant Installed Cost ≈ $675,000

MARINE ENGINEERING TECHNICAL NOTE #8

STEAM GENERATION SYSTEM EVALUATION FOR A 120,000 TON TANKER

DR. DEAN A. RAINS

22 MARCH 1974

J. C. COUCH
Chief Marine Engineer

STEAM GENERATION SYSTEM EVALUATION FOR A 120,000 TON TANKER

ABSTRACT

In Reference (1), a comparison of three propulsion plants was made for a 120,000 dwt tanker. The evaluation excluded consideration of the auxiliary steam generation requirements. This study extends the original study by investigating three alternate generation systems; waste heat boiler on the main engine exhaust, a separate boiler, and, presuming a steam plant for a moment, increasing the steam plant steam rate.

SUMMARY

The study shows that a waste heat boiler on the aircraft gas turbine exhaust is the most economically attractive. A diesel waste heat boiler has insufficient output to match the cargo heating needs of the ship. The higher fuel flow requirements for a separate fired boiler or an increased capacity propulsion boiler makes it unattractive. The results of this study should be added to the annual operating costs presented in Reference (1). When this is done, the aircraft gas turbine has approximately a 7% annual cost advantage over a medium speed diesel.

ANALYSIS

The steam requirements for cargo heating were determined based on the following assumptions:

Cargo Weight = 115,000 Tons

Tank Heating Time = 4 days

Tank Heating $\Delta T°$ Required = 40° (Say from 70° to 110°F or 60° to 100°F)

Steam Pressure - 200 psig

Steam Saturation Temperature - 380°F

Reference: 1) Jeavons, B.T., Rains, D.A. & Cheyne, H.T. - "A Propulsion Plant Comparison for 120,000 dwt Tanker", TN-7 20 March 1974

ANALYSIS (Continued)

The steam requirement is computed to be 67,000 lb/hr A design goal of 80,000 lb/hr was selected to provide some margin. If unexpected heat losses develop the time required to heat the tanks may have to be extended.

Four steam generation systems were examined.

A. Waste Heat Boiler - Main Gas Turbine Exhaust

Assumptions

Gas Turbine Airflow = 150 lb/sec
Engine Exhaust Temperature = 1000°F
Boiler Exhaust Temperature = 450°F
(70° above steam saturation temperature)
Plant propulsion horsepower 24,000 HP
Available steam flow rate from WHB
(Waste Heat Boiler) is

$$\dot{W}_S = \frac{(550)(.24)(150)(3600)}{(900)} = 80,000 \text{ lb/hr}$$

This is a fortuitous match of the needs to what is available. If there is not sufficient steam the cargo heating time can be lengthened slightly.

The estimated WHB installed cost is \$500,000 (1975 Dollars). An expected pressure drop of 5 inches through the unit will increase the plant fuel consumption rate by 0.8% (based on G.E. LM-2500 data). This SFC increase will increase the annual fuel costs by

$$(.008)(.42)(7000)(24,000)(.037) = \$21,000/\text{yr}$$

(7000 Hrs/Year Operations)

(Fuel Cost = \$11/bbl for diesel oil or \$0.037/lb)

In summary, the annual costs are approximately

Equipment Cost (.15 X First Cost)	=	\$75,000
Fuel Cost		\$21,000
Maintenance & Repair Cost		\$10,000
		\$106,000/Yr

B. Waste Heat Boiler - Main Diesel Exhaust

Assumptions

Diesel Engine Airflow	=	36 lb/sec
Twin Engines		12,500 hp/engine
Engine Exhaust Temperature		1000°F
Turbo Charge Exhaust Temp.		820°F

Available ΔT° = 820° - 450° = 370°F

Results

Available Steam Rate

$$\dot{W}_S = \frac{(370)(.24)(36)(2)(3600)}{(900)}$$

$$\dot{W}_S = 26{,}000 \text{ lb/hr}$$

This is about one third of the required steam rate, so this approach was dropped in favor of the separate fired boiler for the diesel engine propulsion plant.

C. <u>Separate Boiler</u>

<u>Assumptions</u>

10 Trips/Yr
Boiler Operates 4 X 10 = 40 day/yr

<u>Results</u>

The annualized first cost of the boiler is 0.15 X $530,000 X 1.40 = $110,000. The escalation cost of the boiler is $530,000. The 1.40 factor covers installation, overhead and fee. The fuel consumed during the 40 days/yr operation is

$$= \frac{900 \times 80{,}000}{17{,}000} = 4200 \text{ lb/hr}$$

$$\text{Fuel Cost/Yr} = 4200 \times 40 \times 24 \times .037$$

$$= \$150{,}000\text{/yr}$$

Thus the total annual costs are:

First cost equivalent	= $110,000
Maintenance & Repair	10,000
Fuel Cost	150,000
	$270,000/Yr

D. <u>Addition of Steam Capacity to Propulsion Boiler</u>

The addition of capacity to the ship's propulsion boiler adds (for 50,000 lb/hr increase) $60,000 to boiler. With installation and fee charges this becomes approximately $13,000/Yr. The fuel cost increase is the same as case C, so the total cost picture is as follows:

Boiler First Cost	$13,000
Fuel Cost	$150,000
Maintenance & Repair Cost	$5,000
	$168,000

A summary of the results is shown in Table I. The total plant operating costs from Reference (1) were modified by the addition of the steam generation system costs. These all inclusive values are shown in Table II. This table shows that the equality between the medium speed diesel and aircraft gas turbine is even closer than in the original analysis.

CONCLUSIONS

The economic evaluation shows that the waste heat boiler addition to a gas turbine is the most attractive, costwise. For the diesel plant a separate fired boiler is required. For a steam plant, adding to the propulsion boiler is most attractive, but less attractive than the waste heat boiler/gas turbi because of the cost of the additional fuel consumption.

The medium speed diesel and aircraft gas turbine continue to be on a par costwise after this study. The separate boiler must be used with the heavy duty gas turbine because of the regenerator so the economic disadvantage of this power plant is increased.

TABLE II

1975 $

PLANT SUMMARY COST ANALYSIS

($ X 10^{-3})

	ANNUAL COSTS			
	MEDIUM SPEED DIESEL	STEAM	HEAVY DUTY GAS TURBINE	AIRCRAFT GAS TURBINE
PLANT COST WITHOUT STEAM GENERATION (REF 1)	$3,260	$3,992	$3,824	$3,345
ADDITIONAL COST DUE TO STEAM GENERATION	270	168	270	106
TOTAL	$3,530	$4,160	$4,094	$3,451

TABLE I

ECONOMIC EVALUATION OF STEAM GENERATION SYSTEMS

CONFIGURATION	ANNUAL OPERATING COST
WASTE HEAT BOILER - GAS TURBINE PLANT	$106,000
WASTE HEAT BOILER - DIESEL PLANT	INSUFFICIENT CAPACITY
ADDITIONAL BOILER - DIESEL PLANT	$270,000
INCREASED BOILER - STEAM PLANT	$168,000

APPENDIX E

LIST OF DRAWINGS AND SPECIFICATIONS

PROPULSIONS PLANT STANDARDS STUDY

LIST OF SPECIFICATIONS: MAIN & AUXILIARY MACHINERY

1. STEAM TURBINES HP & LP
2. MAIN REDUCTION GEAR
3. MAIN CONDENSER
4. 1ST STAGE FEED HEATER , GLAND EXHAUST CONDENSER & DRAIN COOLER
5. 3RD & 4TH STAGE FEED HEATER
6. ATMOSPHERIC DRAIN & INSPECTION TANK & PUMP
7. GLAND LEAK-OFF EXHAUSTER
8. MAIN CONDENSATE PUMP
9. VACUUM PUMP MAIN CONDENSER
10. VACUUM TANK & PUMP
11. MAIN CIRC . PUMP
12. AUX. CIRC. PUMP.
13. S .W. SERVICE PUMP
14. PROPULSION
15. MAIN THRUST BEARING
16. LINE SHAFT BEARINGS
17. STERN TUBE & BEARING, SEALS
18. PROPELLER
19. MAIN BOILER
20. AIR HEATER
21. FORCED DRAFT FANS
22. MAIN FEED PUMPS
23. PORT FEED PUMP
24. BOILER MIXING TANK & PUMP
25. FEED ANALYZER
26. CONDENSATE COMPOUND MIXING TANK&PUMP
27. PRIMARY & SECONDARY SAMPLE WATER COOLER
28. FEED TESTING SET
29. LUBE OIL SERVICE PUMP
30. EMERGENCY LUBE OIL PUMP
31. MAIN LUBE OIL COOLER
32. L. O. FILTER (DUPLEX')
33. L. 0. PRIMING PUMP
35. L.O. PURIFIER
    L.O. HEATER
36. STERN TUBE LUBE OIL PACKAGE
37. MAIN LUBE OIL COALESCER
38. FUEL OIL TRANSFER PUMPS
39. FUEL OIL HEATER
40. FUEL OIL DUPLEX STRAINER
41. FUEL OIL SERVICE PUMP
42. MAIN SWITCHBOARD
43. ENGINE ROOM CONSOLE
44. PUMP CONTROLLERS.

LIST OF DIAGRAMS :

MAIN STEAM
1. AUXILIARY STEAM
3. BOILER FEED
4. CONDENSATE
5. FUEL OIL SERVICE
6. LUBE OIL SERVICE
7. MAIN AND AUXILIARY S. W. CIRCULATING
8. S.W. SERVICE
9. STERN TUBE LUBE OIL SYSTEM
10. BLEED & EXHAUST STEAM
11. MAIN AND AUXILIARY TURBINE GLAND SEAL AND LEAKOFF
12. TURBINE DRAIN SYSTEM
13. STEAM , FRESH WATER, CONTAMINATED DRAINS
14. CONDENSATE DRAIN SYSTEM
15. PROPULSION PIANT CONTROL DIAGRAM
16. BOILER PLANT CONTROL DIAGRAM

LIST OF DETAIL DRAWINGS

MACHINERY ARRANGEMEMT
1. MAIN STEAM
3. AUXILIARY STEAM
4. FUEL OIL SERVICE
5. LUBE OIL SERVICE
6. MAIN AND AUXILIARY S .W . SERVICE
7. S.W. SERVICE SYSTEM
8. BOILER FEED SYSTEM -
9. CONDENSATE SYSTEM
10. BOILER UPTAKES
11. BOILER COMPOUND INJECTION
12. MAIN SHAFTING ARRANGEMENT AND DETAILS
13. CONDENSATE DRAIN SYSTEM
14. BLEED AND EXHAUST STEAM
15. GLAND SEAL AND LEAK-OFF
16. STEAM DRAIN SYSTEM
17. BOILER BLOW SYSTEM
18. LP & HP TURBINE & REDUCTION GEAR BOLTS & CHOCKS
19. PROPULSION PLANT CONTROL SYSTEM
20. BOILER CONTROL SYSTEM
21. INSTRUMENTATION CABLE
22. CONTROL CABLE
23. POWER CABLE

.

PROPULSION PLANT STANDARDS STUDY
MEDIUM SPEED DIESEL PLANT

LIST OF SPECIFICATIONS: (MAIN AND AUXILIARY MACHINERY)

1. MAIN DIESEL
2. REDUCTION GEAR
3. THRUST BEARING
4. SHAFTING
5. LINE SHAFT BEARINGS
6. STERN TUBE AND BEARING AND SEALS
7. PROPELLER
8. MAIN S .W. CIRC PUMP
9. AUX. S.W. CIRC. PUMP
10. ME LUBE OIL COOLER
11. ME LUBE OIL STANDBY COOLER
12. LUBE OIL PURIFIER
13. LUBE OIL HEATER
14. LUBE OIL STANDBY PUMP
15. LUBE OIL FILTER
16. FUEL OIL SERVICE PUMP
17. ME FUEL OIL PREHEATER
18. ME FUEL OIL FILTER
19. ME JACKET WATER COOLERS
20. ME FRESH WATER PUMP STANDBY
21. S.W. STRAINER
22. MAIN SWITCHBOARD
23. ENGINE CONTROL CONSOLE
24. PUMP CONTROLLERS
25. ME EXHAUST SILENCER
26. SHIPS SERVICE AIR COMPRESSOR
27. EXPANSION JOINTS ME EXHAUST SYSTEM

LIST OF DIAGRAMS :

1. FUEL OIL SERVICE
2. LUBE OIL SYSTEM
3.- ME SW COOLING SYSTEM
4. ME FRESH WATER COOLING SYSTEM
 STARTING AIR-SYSTEM
6. STERN TUBE LUBE OIL SYSTEM
7. PROPULSION PLANT CONTROL DIAGRAM

LIST OF DETAIL DRAWINGS:

FUEL OIL SERVICE SYSTEM
1. LUBE OIL SERVICE ARRANGEMENT
3. ME SW COOLING ARRANGEMENT
4. ME FRESH WATER COOLING ARRANGEMENT
5. STARTING AIR SYSTEM
6. MAIN ENGINE AIR INLET DUCTING
7. MAIN ENGINE EXHAUST SYSTEM
8. MAIN ENGINE AND REDUCTION GEAR BOLTS AND CHOCKS
9. MAIN SHAFTING ARRANGEMENT AND DETAILS
10. ARRANGEMENT AND DETAILS STERN TUBE LUBE OIL
11. PROPULSION PLANT CONTROL SYSTEM
12. INSTRUMENTATION CABLE
13. CONTROL CABLE
14. POWER CABLE

PROPULSION PLANT STANDARDS STUDY
LIGHT WEIGHT GAS TURBINE PLANT

LIST OF SPECIFICATIONS: (MAIN & AUXILIARY MACHINERY)

1. MAIN GAS TURBINE ENGINE
2. REDUCTION GEAR (REVERSING)
3. THRUST BEARING
4. SHAFTING
5. STERN TUBE & BEARING & SEALS
6. PROPELLER
7. SHIPS SERVICE AIR COMPRESSOR
8. FUEL OIL SERVICE PUMPS
9. FUEL OIL STRAINER
10. FUEL OIL FILTER
11. FUEL OIL HEATER
12. LUBE OIL SERVICE PUMPS
13. LUBE OIL FILTER
14. LUBE OIL STRAINER
15. LUBE OIL PURIFIER
16. LUBE OIL HEATER
17. S.W. COOLING PUMPS
18. S.W. STRAINER
19. AIR INLET DEMISTER
20. EXHAUST - SILENCER (ME)
21. EXPANSION JOINTS ME EXHAUST SYSTEM
22. WASTE HEAT BOILER
23. MAIN SWITCHBOARD
24. ENGINE CONTROL CONSOLE
25. PUMP CONTROLLERS
26. LINE SHAFT BEARING

LIST OF DIAGRAMS:

FUEL OIL SYSTEM
1. LUBE OIL SYSTEM
3. ME COOLING SYSTEM
4. S.W. COOLING SYSTEM
5. START AIR SYSTEM
6. STERN TUBE LUBE OIL SYSTEM
7. ME AIR INLET SYSTEM
8. ME WATER WASH SYSTEM
9. PROPULSION PLANT CONTROL DIAGRAM

LIST OF DETAIL DRAWINGS:

FUEL OIL SERVICE ARRANGEMENT
1. LUBE OIL SERVICE ARRANGEMENT
3. ME COOLING SYSTEM ARRANGEMENT
4. SW COOLING SYSTEM ARRANGEMENT
5. START AIR SYSTEM ARRANGEMENT
6. STERN TUBE LUBE OIL ARRANGEMENT
7. ME WATER WASH ARRANGEMENT
8. ME AIR INLET ARRANGEMENT AND DETAILS
9. ME EXHAUST ARRANGEMENT AND DETAILS
10. ARRANGEMENT SHAFTING & DETAILS
11. ME AND REDUCTION GEAR, BOLTS & CHOCKS
12. PROPULSION PLANT CONTROL SYSTEM
13. INSTRUMENTATION CABLE
14. CONTROL CABLE
15. POWER CABLE .

PROPULSION PLANT STANDARDS STUDY
HEAVY DUTY GAS TURBINE

LIST OF SPECIFICATIONS: (MAIN & AUXILIARY MACHINERY)

HEAVY DUTY GAS TURBINE
1 REGENERATOR & PIPING
3. THRUST BEARING
4. LINE SHAFT BEARINGS
5.
6. PROPELLER
7. SHIP SERVICE AIR COMPRESSOR
8. FUEL OIL SERVICE PUMPS
9. HEAVY FUEL FORWARDING UNIT
10. DISTILLATE FORWARDING UNIT
11. FUEL FILTERING TRANSFER UNIT
12. LUBE OIL SERVICE PUMPS
13. LUBE OIL FILTER
14. LUBE OIL STRAINER
15. LUBE OIL HEATER
16. LUBE OIL PURIFIER
17. SW COOLING PUMPS
18. FRESH WATER COOLING PUMPS
19. SW WATER STRAINER
20. AIR INLET DEMISTER
21. EXHAUST SILENCER (ME)
22. EXPANSION JOINTS ME EXHAUST SYSTEM
23. HEAVY FUEL ANALYSIS UNIT
24. FUEL WASHING UNIT
25. WATER WASH PROPORTIONING UNIT
26. DE-EMULSIFICATION UNIT
27. FUEL PROCESSING COITTROL UNIT
28. MAIN SWITCHBOARD
29. ENGINE CONTROL CONSOLE
30. PUMP CONTROLLERS

LIST OF DIAGRAMS :

1. FUEL OIL SYSTEM
2. LUBE OIL SYSTEM
3. S. W. COOLING SYSTEM
4. FRESH WATER COOLING SYSTEM
5. START AIR SYSTEM
6. STERNTUBE LUBE OIL SYSTEM
7. ME WATER WASH SYSTEM
8. ME AIR INLET SYSTEM
9. PROPULSION PLANT CONTROL DIAGRAM

LIST OF DETAIL DRAWINGS:

1. FUEL OIL SERVICE ARRANGEMENT
2. LUBE OIL SERVICE ARRANGEMENT
3. SW COOLING SYSTEM ARRANGEMENT
4. FRESH WATER COOLING ARRANGEMENT
5. START AIR SYSTEM ARRANGEMENT
6. STERNTUBE LUBE OIL ARRANGEMENT
7. ME WATER WASH ARRANGEMENT
8. ME AIR INLET ARRANGEMENT & DETAILS
9. ME EXHAUST ARRANGEMENT & DETAILS
10. ARRANGEMENT SHAFTING & DETAILS
11. ME & REDUCTION GEAR BOLTS & CHOCKS
12. PROPULSION PLAINT CONTROL SYSTEM
13. INSTRUNENTATION CABLE
14. CONTROL CABLE
15. POWER CABLE

APPENDIX F

COMMENTS FROM SUPPLIERS

MAIN PROPULSION STANDARDIZATION SURVEY

RESPONSE FROM VENDORS

SEVERAL VENDORS WERE CONTACTED IN AN ATTEMPT TO GATHER THEIR OPINIONS ON THE FOLLOWING QUESTIONS:

1. Need for upgrade of present purchasing methods.
2. Desirability of standardized procurement specifications.
3. Value of development of complete sets of detail interface plans for each component. These plans to be pre-prepared prior to the concept or reward of a contract.
4. Value of development of equipment with identical interface of the various competitors.

STEAM TURBINE

DeLaval. Trenton, .New Jersey., . Mr. Don-. Carpenter. .

1. Some improvement could be made from the present method.
2. Would be in favor or standards providing they were so written to permit the use of their present design.
3. Development of a pre-package of plans could be done. They would only consider this if the entire industry went this way. There would be some cost involved flat would have to be borne by someone else.
4. Complete interface isn't practical. They.feel that they have an advantage due to their heavier weight of castings. This gives them-a smoother running turbine.

General Electric, West Lynn, Mass., Mr. G. A. Cincotta

1. No comment.
2. General specs would be satisfactory. However, the present .MarAd Specs need updating. They should be reviewed by the various Mfg. to assure compliance with their standards.
3. Pre-prepared detail plans not feasible. G.E. uses a conpon system and can achieve a variation of conditions by Switchi parts. This alters the application drawings. they feel th they would have to be involved' and no time savings is anticipated.
4. Could not consider interface. Would mean redesign of the equipment.

Westinghouse, California, Mr. Fred Hassett

1. Some improvement needed.
2. In favor of standard specs to force all vendors to bid on like equipment. Feels that it would be good for all.
3. Pre-plans would be very expensive but could be done. Felt that some funding would be required.
4. This phase would be quite difficult. Could be considered if all vendors would be willing to modify to suit others. Extremely expensive.

DIESEL DRIVE

Pielstick, New Orleans, Mr. Larry Lynch

1. No comment.

2. Could be done but would rather have specs written around specific equipment. Felt that standard specs wouldn't properly describe the equipment.

3. Could be done. In fact he felt that they had done this with catalog data. I explained that we were discussing an approved package ready for release. He still felt that it was possible but that there would be some exceptions that would take negotiations.

4. Felt that it would be impossible for competitors and they would only consider it if others modified their equipment to *suit* Pielstick. standards.

PUMPS

Worthington Pumps,New Jersey, Mr. Ken Hill

1. There is some need for upgrading.

2. Not entirely opposed but velt that the present MarAd Specs needed upgrading. He pointed out that many materials had been replaced by better ones. He also felt that it would be necessary to consider all vendors substitutions to permit competitive bidding. Also stated that the Specs must be kept current with times.

BOILERS

Combustion Engineering, Windsor, Conn., Mr. Steven Sabo

1. No comment.

2. Feels that the specs would have to be so general that almost anything could be built. Would be unfair to vendors. Also would have to be upgraded to be a satisfactory final spec.

3. Feels that the"owners would object unless MarAd would be willing to set an edict forcing Owners to accept standards. He felt that general sizes would be O.K. but final details would differ in final development.

   Could not see how this would be possible. Mentioned the possibility of favoritism.

GAS TURBINE

General Electric Co. , Mr. Dan Vano

1. Feels that present method of approach is satisfactory.
2. General specs would be O.K. but details would still have to be developed.
3. These people depend on combinations to meet design conditions. They feel that it would be necessary for them to be in the final selection of equipment. Should the builder proceed with the design immediately the engineers would object to changes as the final selection is made.
4. Felt that this is impossible.